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# JOURNAL

OF THE

# AMERICAN WELDING SOCIETY

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# American Welding Society

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# JOURNAL
## OF THE
# AMERICAN WELDING SOCIETY

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# AMERICAN WELDING SOCIETY

ESTABLISHED 1919

# JOURNAL

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## ANNUAL MEETING

The Fourth Annual Meeting of the Society, in accordance with the by-laws, will be held from April 25 to 29th, inclusive. The Meetings and Papers Committee are planning to have this meeting the largest and most successful in the history of the Society. Several welding papers of national interest are being prepared. Inspection trips and social sessions are also being given consideration.

The Welding Society has made progress during the past year and thru its endeavors the various welding processes are being used in new fields and with better results in the old ones. This progress will be clearly brought out at the annual meeting. Arrange your plans so that you can attend.

## HELPING THE SOCIETY

The amount of work which any technical society can do is in proportion to the number of its members. Every new member means an additional push to a united effort. A greater membership allows greater activities and greater returns to each member.

There can be no question but what some of your friends and business acquaintances should become members of the American Welding Society. You will be shortly in receipt of a card signed by the President requesting that you furnish the names of at least three of your friends who should become members of the Society. As soon as we receive this information we will write them promptly. You can further assist by personally urging each to study the literature so received and thus become acquainted with our good work.

## WELDING MANGANESE STEEL

The American Bureau of Welding is in receipt from time to time of requests for information as to the proper methods and materials to be employed in the welding of manganese steel. The Bureau at the present time is not in a position to answer these questions with the same assurance that it handles other welding problems.

Beginning with the next issue, we are planning to publish in the Journal, under the Technical Question and Answer Column, all communications that we receive on the subject. If you have any information on the welding of manganese steel in any of its phases, kindly send it to Secretary W. Spraragen of the American Bureau of Welding, 29 West 39th Street, New York. Some of the points that might be covered in this connection are: (a) previous successful experience, (b) details as to how welding should be done, (c) precautions to be taken, (d) reasons for previous failures, (e) detailed description of methods or material that have proven successful in the welding of manganese steel, (f) bibliography.

## WELDED RAIL JOINTS

A meeting of the Welded Rail Joint Committee will be held at the Bureau of Standards in Washington on Saturday, February 17th. Among the items that will come up for discussion will be the detailed specifications for each type of test to be used by the Committee. These tests include tensile, bending, repeated impact, drop, conductivity and service wear tests.

## WELDED PRESSURE VESSELS

One of the many difficult problems concerning the Boiler Code Committee of the American Society of Mechanical Engineers in its effort to draw up satisfactory codes governing the construction of unfired presssure vessels is welding. Rules applicable to riveted constructions do not always apply to fabrication by welding.

The problem is seriously complicated because of the meagreness of scientific data upon which to base proper requirements for safety without without placing

unjust restrictions on the use of welding. Wide differences of opinion prevailed not only amongst the members of the Committee, the insurance companies and inspectors, but also in the industry itself.

A hydrostatic and hammer test was finally proposed for determining whether a vessel was safe for the purpose designed. The American Bureau of Welding, which is the advisory committee on welding research for the American Welding Society and the National Research Council, organized a Pressure Vessel Committee to co-operate with the Boiler Code Committee in determining the adequacy of the test proposed. Eight manufacturers placed at the disposal of the committee some forty tanks and enough funds. These tanks have been tested to destruction by the U. S. Bureau of Standards.

The shells of most of the tanks were 6 feet long and 2 feet in diameter, and made of $\frac{3}{8}$ inch mild steel plate. Both electric and oxy-acetylene welding were used. The hydrostatic and hammer test developed that the welded pressure vessel, according to the regular formula for working pressure, has a factor of safety of about 6.

A remarkable feature of this undertaking is the rapidity of accomplishment. The first meeting of the committee was held in New York on August 17, and a plan outlined. The tanks called for in the program were immediately built by manufacturers distributed widely, (one of them on the Pacific Coast) and shipped to the Bureau of Standards in Washington. Most of the tanks arrived by the first of December. Under the supervision of Dr. H. L. Whittemore, Chief of Section VII-1, Physical Tests of Structural Materials Division, who is also Chairman of the Committee, testing was started December 4 and carried on continuously to January 10. Many visitors, including members of the Boiler Code Committee, insurance inspectors, tank manufacturers, American Welding Society and National Research Council, have witnessed tests. A report is being compiled and will soon be published. This program including tanks, testing and incidentals, involved a sum of $15,000.

The manufacturers co-operating in this work are: York Manufacturing Company, Pfaudler Company, Elyria Enameled Products Company, Union Carbide and Carbon Corporation, DeLaVergne Machine Company, Coast Culvert & Flume Company, Brunswick-Kroeschell Company, and Vilter Manufacturing Company.

# SECTION ACTIVITIES

*Boston*

The January meeting of the Boston Section was held on the 19th at the General Electric Company's River Works Plant, West Lynn, Mass.

*Editor's Note*: Thinking that a complete account of this meeting will serve as an example of how section meetings may be successfully arranged, we are giving below a detailed report by Secretary J. W. Morrisey:

"This meeting, which lasted from 2:00 to 10:00 p. m., and which was attended by over 400 members and their guests, was the largest yet conducted by the Boston Section, and must rank as one of the most notable meetings ever held by the Society independently of other engineering bodies. The Program was interesting and varied—the lecturers were authorities on their subjects; the practical demonstrations, which were done on a scale hardly attempted before, were particularly interesting, and all present expressed themselves well repaid for any inconvenience experienced in attending.

The Boston Section in particular, and the Society in general, owe the General Electric Company an expression of gratitude and appreciation for their hospitality and general assistance, and a tribute for the admirable way in which the lengthy program was conducted.

The afternoon was spent in the Welding Department, where practical demonstrations were held. As the members and their guests arrived they were divided into groups of ten or a dozen, and conducted about the exhibits. There were on view examples of hand arc welding, metallic and carbon; semi-automatic welding; automatic welding, both seam welding with the work stationary and the electrode head moving, and building up of shafts and car wheel rims where the work revolves and the electrode head is stationary; automatic forging of the automatically built up wheel rims and flanges by an air hammer closely following the electrode head. These different kinds of arc welding were displayed on a variety of work, for example tank welding, the wheel welding referred to above, light structural work, etc.

In addition to the arc welding there were demonstrations of resistance and acetylene work, and of oxy-hydrogen cutting.

All these operations were explained in detail by Malcolm Thomson and his assistants, who pointed out interesting and important details which might otherwise have passed unnoticed.

After viewing the exhibits of the work each party was conducted to the theatre, were an entertainment was in progress during the interval necessary for all to assemble.

At 4:00 o'clock Prof. Elihu Thomson, honorary member of the Society and one of the active Boston Section members, opened the meeting proper. After a few words of welcome and of explanation of the purpose of the Society in having such meetings, Prof. Thomson introduced Mr. Enbanks of the W. W. Lyas Company, Providence, R. I., who gave an instructive lecture accompanied by moving pictures entitled "How an Automobile is Manufactured in an up-to date Shop".

Following this lecture a period was devoted to discussion, and in the supper hour which followed an opportunity was afforded to meet old acquaintances and form new ones. Supper was served in the dining room of the main administration building and both before and after it the gathering was entertained by Larry Semon, Harold Lloyd and others through the medium of moving picture comedies.

After supper Prof. A. S. Kinsey, of Stevens Institute spoke on the accomplishments of the Society and indicated fields for further activities.

Mr. Glassup of the General Electric delivered a lecture, illustrated by moving pictures and slides on "Automatic Arc Welding" and its application. Then Mr. T. A. Wry, Chairman, and Mr. J. W. Morrisey, Secretary of the Boston Section, took a few moments to speak of the plans and ambitions of this young and very energetic Section and to solicit the financial and other support necessary to materialize its prospects.

Mr. Charles A. McCune, President of the Society, was then introduced and after a brief address to the members of the Boston Section completed the program with an exposition of the manufacture of the commercially pure "ARMCO" Ingot Iron, accompanied by an exceptionally fine moving picture. This gave the audience a clear idea not only of open hearth steel practice, but also of the special processes and safeguards taken in the manufacture of a specially high grade product like "ARMCO" iron.

The gathering was representative and included members of the various steam and electric railways, large manufacturing companies and of the independent welding companies.

All expressed themselves highly pleased with the meeting.

*Chicago*

The subject of Training of Operators was scheduled for discussion at a meeting of the Chicago Section to be held February 2, 1923.

*Cleveland*

A meeting of the Cleveland Section will be held on February 8th at Cleveland Engineering Society at Hotel Winton, Ballroom. Mr. D. H. Deyoe, Engineer, General Electric Company, will present a paper on "Automatic Arc Welding," illustrated by moving pictures.

*New York*

The January meeting of the New York Section was held in the Engineering Societies' Building on the 17th. Mr. E. S. Eldridge of the D. L. and W. R. R., Kingsland Shop, presented a paper on "Practical Welding." About 65 people were in attendance. The paper aroused considerable interest and discussion, particularly by the welders present.

*Northern New York*

A combined meeting of the Northern New York Section was held on January 19th with the local Section of the American Institute of Electrical Engineers, Mr. E. H. Ewertz, General Manager of the Moore Plant of the Bethlehem Shipbuilding Company, delivered a paper on "Arc Welding as Applied to Shipbuilding." In his paper Mr. Ewertz dealt with the problems of the design of ships and described early methods used in the construction of joints. He also gave an historical review of the application of arc welding to ship construction in England and America.

*Philadelphia*

Mr. E. E. Radcliffe, District Sales Manager of the Linde Air Products Company, presented a paper before the January meeting of the Philadelphia Section held on the 15th dealing with "How to Handle Process Problems."

*San Francisco*

At the October Meeting of this Section, Mr. K. V. King, Metallurgist to the Standard Oil Company of California, presented a paper on "Autogeneous Welding in the Petroleum Industry." The meeting of the San Francisco Section was scheduled for January 20th. Mr. W. P. Brown of the Brown Brothers Welding Company, one of the oldest and best known welding concerns on the Pacific Coast presented a paper dealing with welding problems as met in the job shop. A very large number of slides illustrating interesting and unusual work was shown.

## EMPLOYMENT SERVICE BULLETIN

To meet the demand of its members, the American Welding Society maintains an Employment Service Bulletin. The bulletin is divided into two sections—POSITIONS VACANT and SERVICES AVAILABLE. No charge will be made either to the available engineer, foreman or welder, or to the organization seeking welding talent. The number of opportunities for employment of which the Society has knowledge does not at present equal the number of men whose services are available. The co-operation of members of the Society, industrial establishments and others needing the services of men trained in the various branches of welding is earnestly desired. The location, necessary qualifications for each position and the approximate salary, if possible, should be stated in each case.

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the bulletin.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcments will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the Thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the Number Indicated in Each Case and Mailed to Society Headquarters.*

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## SERVICES AVAILABLE

A-17—RESEARCH DIRECTOR: Engineer experienced in organizing Research desires to secure position as director or manager of a Research Department of an Industrial Corporation. Can organize new department or successfully operate or reorganize one already existent.

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## EMBLEM

All members of the Society are privileged to wear the Society emblem. Emblems may be obtained in two styles from the Secretary's office. Price, gold-filled, 75c., 14-K. gold, $5.00.

# AUTOGENOUS WELDING IN THE PETROLEUM INDUSTRY*

K. V. KING†

Autogenous welding has become a necessity to the Petroleum Industry. Welding has reached its present value in practically every branch of the oil industry only through a long period of development in which step by step it has been found and proven to offer a means of construction which usually results in greater economy, which enables the construction of equipment that oftentimes could not otherwise be built and which above all gives increased safety of operation.

Welding with the Standard Oil Company of California first started in 1911, and since then has steadily increased in amount until in 1920 an average of 148 acetylene and electric welders and helpers were employed by the Company with a maximum for that year of 290 in August. From January to September 1922, inclusive, there has been an average of 132 with a maximum of 189 in August. The greater number employed in 1920 was due to an unusual amount of construction work. However, the uses to which welding is being adapted are continually increasing.

In discussing welding practice, the first consideration should be the welders, themselves. One of the principal objections raised against fusion welding processes is that the quality of welds depends largely upon the ability of the welder. We realize and recognize this and have tried to meet it by the selection and instruction of the welders and by continual watch over the work. When hiring welders from the outside, we assume that they know their trade but give each one a test or tryout to see if he meets our standard. This tryout consists of making a "V" weld in $\frac{5}{8}$ inch or $\frac{3}{4}$ inch plate lying flat and vertical and in welding 6 inch pipe held stationary, thus requiring overhead welding. This test, of course, is not severe but is sufficient for our foremen to judge the applicant's ability. During the last year only 40 per cent of those who tried out have met our standard and when employed they are placed on welding that is not subjected to high pressure or high temperature. Their welding is observed and they are instructed in our methods. Those who demonstrate sufficient ability are placed on high pressure work. Such a tryout is of particular advantage to men seeking employment as well as to the Company. It is recognized that commonly tradesmen are better qualified in some particular branches of their trade than in others and that by such tryout their ability is immediately demonstrated. When

†Metallurgist, Standard Oil Company of California.

*Abstract of paper read before American Welding Society, San Francisco Section, Engineers Club, San Francisco, Cal., October 20, 1922.

employed their future is less in doubt as they have assurance that they should be able to give satisfaction.

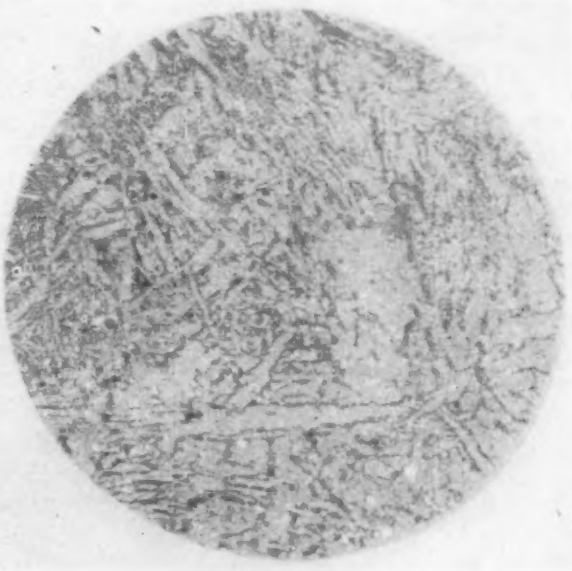
The material to be used in welded construction should be the next consideration. It is very desirable to use low carbon steel since it is not as susceptible to over-heating, burning or oxidation and there is not the sudden difference in physical properties between the weld and the plate. It is well to make a distinction here between overheating and burning. A weld or any steel which has been overheated will have a coarse grain structure and be somewhat brittle. It can be restored, however, to a satisfactory condition by heat treatment. On the other hand metal that is burnt can not be restored by any heat treatment or mechanical work. This is true because there has been an actual formation of scale or oxide around the crystal boundries of burnt steel. In addition to being low in carbon, the steel should be low in impurities.

Referring especially to containers used in oil refining processes special welding grade, firebox or flange plate, depending upon the purpose, is used for our welded construction, and precautions are taken that pipe used in particular services is open hearth steel. A thorough investigation is under way covering the use of alloy steels in vessels particularly when subjected to high temperature. The use of these metals will not be undertaken until every possible factor has been taken into consideration.

The ripple weld is used on steel plate under ½ inch thickness. For material heavier than ½ inch, particularly when subjected to pressure and temperature, we hammer the weld while the temperature of the metal is within the critical range. Since the weld is originally a cast structure, hammering, which is in the nature of a forging operation, produces a finer grained structure and a metal that is more resistant to vibratory loading. Care is taken to stop the hammering at a temperature where the color is about a cherry red for below this temperature it does no good and may cause injury by setting up cold strains in the metal. Particular care should be taken to avoid setting up cold strains in metal that is to be subjected to operating temperatures above about 800° F. as grain growth may result.

It is our practice to anneal all acetylene welds. There is a question as to the necessity of doing this, raised particularly by some of those doing commercial work. There seems to be no doubt, however, as to its desirability. Our attitude is that we want the best construction we know how to obtain. Considerable experimental work on various methods of annealing has been done. Small portable furnaces heated by an oil torch, to encircle a weld in 6 inch to 12 inch pipe have been built but difficulty has experienced in maintaining a lining. The method now used is to reheat the weld with the acetylene torch using a large flame. Pipe bends with welds in them are placed in a large furnace and the entire bend annealed. Pyrometers are installed in all our flanging and heat

treating furnaces. When annealing with the torch the weld and the metal adjoining are heated to a temperature of probably a little over 1600°F., or a salmon color, and allowed to cool slowly. This is done for the purpose of (first) relieving the welding strain, (second) annealing the weld metal to reduce the grain size and make it more ductile, and (third) to remove any coarseness of grain in the base metal adjoining the weld. It is realized that the annealing temperature of the deposited metal is higher than that



**Metal Deposited in Weld.**
(100 Diameters Magnification).

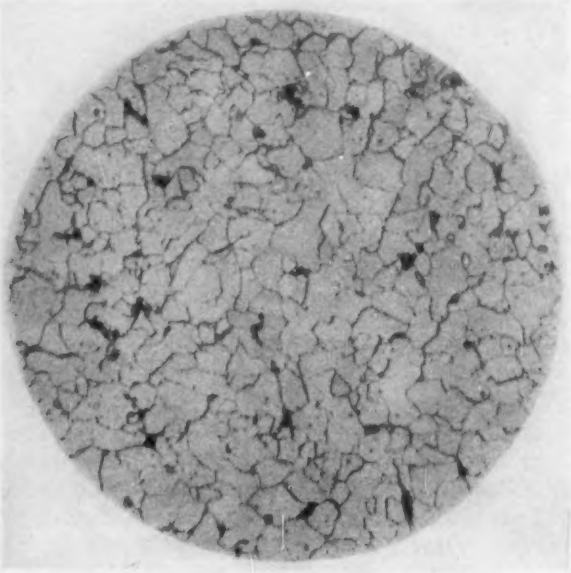
of the base metal, but it is thought that the beneficial effects of refining the deposited metal are greater that the harm that might result from the possibility of overheating the base metal.

The photomicrographs show typical structure of deposited metal before annealing and after annealing with the torch. It has been found that annealed welds consistently show greater elongation over the welded area when tested and they may be bent through a greater angle than when unannealed

For our usual or routing tests in the welding shop we do not have tensile specimens made but merely bend the welds in a press. One edge of the weld is often ground smooth and etched with ammonium persulfate solution*. This solution is much more effective in developing structure visible to the naked eye than is nitric acid solution which is commonly used. It is interesting to note that electric welds which have been improperly fused into the base metal will be clearly indicated by this etching. Our bend tests are

*This solution is fully discussed in Scientific Paper No. 420, of the Bureau of Standards.

not confined to specimens purposely made for testing, but after every piece of large construction work the Shop Foreman will promiscuously mark out places on the welds to be cut out and bent. This serves as a check upon the type of work going into structures, and in addition it has a desirable effect on the morale of the welders. They know the quality of work required and they know they will have to produce it. It has been gratifying to find that all such specimens cut from actual work have always in-



**Metal Deposited in Weld After Annealing With Torch.**
(100 Diameters Magnification).
Same Area as Shown in Other Photograph.

dicated high quality welding and we thus know that our method of control and supervision is giving us the results that we want. There is no doubt that the standard of our work is continually improving. One of the changes in the last year is that all welding on pressure containers is stamped by the welder with his identifying number so that there is a record of which welder has made each part of the work. Thus it is possible to place the responsibility for good or bad welding.

The study of welds and castings by X-Ray examinations has been considered, but after going into the subject somewhat it was decided that there is apparently little practical application in its present state of development. Magnetic testing has been considered and seems to offer possibilities of development to a state where it may be successfully used.

The applications of welding made in the Petroleum Industry are very extensive and ever increasing and extend to practically every branch of the industry. When oil first comes out of the ground it must as a rule be passed through "gas traps" to separate out any gas that it may carry. These traps used to be constructed with threaded connections but are now built by welding which offers a much cheaper, qùicker and more reliable method of construction. A large part of the gas production in the oil fields carries a considerable volume of gasoline much of which can be recovered by passing the gas through compressors and then cooling it in a spray tower. Many of the plants for accomplishing this have a capacity for handling millions of cubic feet of gas per day and the coils in which this gas is pre-cooled, intercooled and after cooled utilize miles of pipe. If these coils were all made up with screwed joints and manifolds they would be very costly and probably subject to serious leakage. By the use of welding they can be made very compact and are practically free from leakage. Welding is also used extensively in gas absorption equipment. In pipe line transportation welding has become practically standard in the construction of gas lines. Welding has only recently been applied to the construction of oil lines but it promises to make an equally favorable showing in this important phase of the petroleum business. Acetylene welding has almost become a standard in the construction of pump house manifolds.

It is of course at the refineries that welding is finding its greatest fields of usefulness. Electric welding is used more in the refineries than in the field and the applications for it have gradually increased until at present a third to a half as many electric as acetylene welders are employed. This proportion, however, varies as the character of the work to be done changes.

Acetylene welding of pipe lines that are subjected to high pressure of hot oil is good practice. This is desirable as it reduces leakage and presents a joins about twice as strong mechanically as a threaded connection.

This mechanical strength is necessary as proper precautions are not always taken for expansion stresses and failures in screwed connections may result. Welded manifolds are particularly desirable as it is sometimes very difficult to hold light lubricating oils with screwed fittings.

Welding has been useful on structural work for clay elevators, spouts, hoppers, chutes and dryers and for large filters and storage pans in the lubricating oil plants.

Experience has shown that electric welding of riveted crude stills on the bottom inside caulked seams and around the rivets will make enormous savings in repairs. Without the welding, the lap on the bottom sheets buckles up and coke is deposited which produces leaks and makes further caulking difficult.

It has been found that electric welding may be successfully used for repairs to tank bottoms, the patches whether large or small being laid on the bottom and electric welded. This may be economically used for completely renewing bottoms in large tanks as the necessity for raising the shell is thus obviated. Roofs on the new tanks may be electric welded instead of riveted, thus making the roof tight and possibly making the construction more economical.

In boiler houses welding may be used extensively. Acetylene welding of steam manifolds or headers is a satisfactory method of construction and eliminates more or less continual leaks on screwed connections. Reinforcing of calking edges of the heads of return tubular boilers by electric welding has been found satisfactory. This will reduce repairs enormously. Reinforcement of flue holes by building up with electric welding and then reaming out has saved flue sheets that would otherwise have to be removed and scrapped. The welding of the beading on the tubes on the combustion end of the boilers will materially reduce the leaks.

An experimental laboratory of an oil company is really a miniature refinery, and welding has been found to be far the most desirable method of construction of such small apparatus.

In an asphalt plant acetylene welding has been found to be suitable for making vapor lines and expansion joints, steam jacketed asphalt headers, and steam jacket manifold nozzles for filling barrels.

In pressure still construction, acetylene welding may be used extensively to advantage, and in many places it has been found that such construction is not possible without welding, and furthermore, it is the only safe method. Experience has proven that with the use of qualified welders, high class material and close supervision, acetylene welding may be successfully used on vessels with ½ inch, ¾ inch, ⅞ inch up to 1 inch shell thickness that subsequently will be operated under pressure and at a high temperature.

Welding has been used for the repair of steel castings that, due to their design and the requirement of prompt delivery, presented difficulties to the foundry.

The Petroleum Industry calls for but little cast iron welding with the exception of some repair work. There is also but little use for aluminum welding. There is, however, considerable brazing done, largely on repairing iron barrels.

Realizing the importance of welding and the desirability of using the highest quality methods and practices throughout the entire company the Engineering Department, together with those experienced in welding, compiled in 1921 what was termed a Welding Manual. This covered the conventional, established, general information applicable to and of specific value to our own particular work. It was circulized to those in authority over welding throughout the Company and has served a good purpose. It covered in part safety regulations for you must realize that welding in the

oil industry must be done with unusual precautions. Some of these are that a fire permit signed by three designated persons in authority must be obtained before welding is done on refinery equipment, that a welder must always have with him a fire extinguisher when working within certain boundries, and that all equipment which has contained oil must be thoroughly steamed and have steam flowing through it while welding is being done.

This has given a general idea of the extensiveness of the use and the importance of autogenous welding in the Petroleum Industry. Autogenous welding has been successfully applied for these many purposes as we can truthfully say that our company has never had an accident or failure due to defective autogenous welding alone. That is a broad statement but true. Welding has become a necessary art from the standpoint of economy, from the stndpoint of enabling the building of structures that otherwise could not be done, and from the standpoint of increased safety of operation in refining.

In our continual effort to obtain the highest quality welding possible the welders have always given their hearty co-operation and we have found that they can be depended upon to take interest and pride in their work.

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## CO-OPERATIVE TRAINING IN THE AUTOMOBILE INDUSTRY*

ALBERT SOBEY†

Everyone undoubtedly recognizes that all industry has one common product. Regardless of whether our manufactured products are automobiles, locomotives, pianos, or welding apparatus, we are also producing this universal, most important product, men. The development of the men and women employed is one of the most important functions of any industry, and presents problems that in their general aspects are common to all and therefore the experience of any industry or community in dealing with them should have elements of value to all.

A great deal of time and effort has been spent during the past ten or fifteen years on so-called scientific management, standardizing machine operations, development of time and motion study, planning boards and other more or less mechanical methods of production control. This work has brought wonderful advancement to industry, but until quite recently one of the most vital factors

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was overlooked. These mechanical features must be carried out by human beings whose ability, fitness for and attitude toward the job are bigger factors than stop watches and card catalogues. The evident inefficiency of labor during the boom period following the war and the tremendous increase in efficiency brought about by the operation of one incentive—the necessity of holding the job during the period of depression—has proved this conclusively.

A few days ago, William Judson Kibby, the noted Industrial Psychologist, made the statement that at least 70 per cent of the employees of industry are more or less mis-fits.

This represents a tremendous human waste, a tremendous loss in aspirations stifled, talents undeveloped, ambitions thwarted, that cannot do otherwise than result in correspondingly large productive wastes.

Every man has certain characteristics and abilities that fit him for certain lines of work.

The most important function of industry is to provide the means for its employees to develop their lives by doing the thing they are best fitted to do, and in the doing of which they derive the greatest satisfaction. When industry adequately fulfills this function, efficient production will follow as a matter of course.

There are, of course, many factors involved such as: The proper analysis and selection of men; adequate training; a close co-operation between employing and training agencies to bring men and jobs together under proper auspices, and through the proper application of what has been called sentiment in business, developing a spirit of true co-operation, a conception of the organization as their organization, in which each man on his job may work out his life in the satisfactory doing of the thing he is best fitted to do. In addition, provision for recreation, social contact, industrial insurance, etc., have their place.

Acetylene welding has quite a varied application in the automotive industry. It is used extensively in the body plants in welding together the sheet metal panels. It is also used in the sheet metal plants in welding heads on mufflers, repairing defects in sheet metal parts, and in quite a number of similar ways. In most of the other plants, it is used more largely for repair work, the type ranging from heavy repair jobs on stamp heads in the forge plant, salvage work on defective castings in the foundry, general repair work in the machinery repair plants to minor salvage work in connection with machine operations in production. Outside of the body plants only one or two men, usually only one, is employed for welding work, and in many cases, in addition to the welding, he has other duties.

In view of these facts, it is evident that a training agency in our position would have to prepare its men to go out into any of these lines of work. This involved the organization of a general course covering all of the various phases of welding, as applied in

the automobile industry, particularly sheet metal, cast iron, aulminum and the use of the cutting torch. Such a general course was organized, and has been successfully conducted during the past two years. Following this, we have provided a continuation training for men who either were placed in particular lines of work, or who desired to specialize, in which cases instruction is entirely individual and specialized.

Mr. Viall, in his recent book says that to become a first-class all around welder requires practice and lots of it, a mechanical sense and a liberal application of brains as the flux on each job. The men who come to us for training are all employed or are looking forward to employment in the automobile industry, and therefore, in practically every case, are men with mechanical ability. In organizing our training program, we were therefore interested in the other two features mentioned by Mr. Viall: namely, practice and the application of brains.

In training men for any particular line of work, we believe attention should be given to the so-called theoretical and technical features, as well as, the practical side of the work. In other words, we aim in so far as possible, to train the student in the underlying principles involved in his work and the "why" of every operation, as well as in the method of doing it. A knowledge of the principles underlying the work makes possible an intelligent application of brains, and the mechanical skill is obtained from the practical work.

This is the basis of our course for welders, the training offered emphasizing both the technical and practical features of welding.

The technical features are largely covered by home study with only a sufficient amount of attention in the classroom to enable the student to effectively carry on his home work. This home work is carefully laid out, a student lesson sheet being given to the student for each class period, which gives definite assignment for study, outlines the main points covered in the assignment, and gives a series of questions which are designed to emphasize and fix these points in the student's mind. The home work is organized with a view to enabling the student to study the principles involved, and be prepared for the practical work that he will do during the next class session.

Practical work is strongly emphasized throughout the course and the major part of each session is devoted to welding operations performed, under the direction of a man of years of experience, who is generally recognized as the most accomplished welder of the Buick Motor Company. While a strictly practical welder, he appreciates the value of the knowledge of the technical features of the work and has been very successful in holding the interest of every class he has had in his charge.

Until this year the school made use of the factory equipment of the Buick Motor Company exclusively for this training. We had some little difficulty, however, in a few cases in avoiding conflicts

with production, and for this year have installed in the Buick plant our new equipment, which is connected to the duplex Oxweld Generator, with which this plant is equipped. This gives us the advantage of special class equipment reserved entirely for our use, with the facilities of the Buick plant at our disposal.

The practical training in the class is based on the carefully organized series of jobs following a definite instruction order. These jobs were originally laid out by the instructor and revised in the light of the experience we have had over the past terms, and are now being organized into a series of job sheets, indicating operations to be performed, precautions to be taken and instructions as to the method of performing each particular job. These job sheets, together with lesson sheets makes our course of training definite and reduces to a minimum any change that would occur with change of instructor, which is always a possibility in work of this nature.

We keep our classes in training of welders small, about ten or twelve constituting a class under ordinary circumstances. This permits ample personal supervision on the part of the instructor.

The first session of each course is devoted to class organization and an outline of the course. The next two are devoted to a study of the welding equipment, torches, generators, etc., and adjustment of the flame. Special attention is given to flame adjustment, every student being given a thorough drill in obtaining a neutral flame. The importance of maintaining a proper adjustment is kept before students thoroughout the entire course.

Welding operations are started at the fourth session with a simple job of welding together two sheet metal strips $\frac{1}{4}$ x $1\frac{1}{2}$ x 12. The work with steel includes different types of jobs, special attention being given to welding metal of 18 or 20 gauge, such as is used in automobile bodies.

Following the work in sheet metal, the welding of cast iron is taken up beginning with strips approximately $\frac{1}{2}$ x 10 and including work in thinner castings and more complicated pieces. The importance of preheating is stressed in this connection, a preheating furnace being available in the plant, and also considerable work in building up is given.

One session is usually devoted to welding copper and brass and one to the use of the cutting torch.

Considerable attention is given to the welding of aluminum. We usually get our jobs for this part of the course by breaking up scrap crank cases into pieces of suitable size and welding together the broken pieces. Heretofore we have given no attention to welding sheet aluminum but some of the local companies are very much interested in this particular work at present, and we are planning to give it some attention this term.

Throughout the course the students are given various production jobs which must pass regular factory inspection. This work

is usually given as a test at the beginning part of a class session, after the student has finished the part of the course dealing with that particular metal. These jobs provide very practical tests and are welcomed by the students.

Regarding results, the organization of this program was begun by the writer three years ago. During this period the total enrollment for all courses has been about 3800 or an average of over 400 per term. Of those who have enrolled, a very large percentage have finished in normal terms, the percentage for one term reaching 94. We suffered severely when the factories practically shut down during the depression, however, at that our percentage per the three years is 68.

We have given most of our attention so far to organizing and conducting the courses. We have, however, made reports of the progress of the men to our committee—men in the factories, the plant superintendents and employment departments. This brings the men in training to the attention of the plant executives and a very considerable number have profited in better positions, increased pay, etc. Just the other day the manager of Buick 28 stopped me and said, "Hicks might be a good reference for you; when he started his training, his bare rate was forty cents per hour, now it is seventy-five cents and he is one of the best men we have." Hicks took our welding and machine shop practice course, and is handling all the welding work in 28, and also some work in machine repair. I could give many similar instances and undoubtedly a large number have never come to our attention.

Now that the program is in a more complete state of organization, however, we are working out a definite plan of placing the students in the type of work for which they are training. In this we are co-operating with the employment departments of all the factories of Flint. in laying out a plan whereby students at certain stages of training along particular lines will be placed on preferred employment lists for work of that nature, in all of the factories of the city, so that as openings present themselves, they will be given first consideration. In order to make such a plan effective, our instructors make monthly reports in regard to their students. Those reports involve four factors: the students attendance record, his standing in the class from a more or less scholastic standpoint, his percentage of improvement and a general rating as to his qualifications for a position along that particular line. We believe that this plan enables us to place men in positions for which they are best fitted with a considerable degree of precision.

# HOW TO HANDLE PROCESS PROBLEMS*

E. E. RADCLIFFE†

All of us who are interested in the welding process and the use of the cutting torch frequently encounter problems in application. We know that in the past many of the problems have seemed to be so serious that no real attempts were made to overcome them and the process was, therefore, not used.

As members of this Association we have a moral obligation to study how to overcome obstacles. Unaided, however, each one is limited in ability to undertake work, and the question is where to go for help. My answer is to consult an engineer specializing in process work. Should the first man consulted not be able to solve the problem, it would be well to consult others—calling upon those who have as broad experience as possible.

There are many ways in which problems may arise in an industry—some of them may be operative; some may be in the nature of routine business such as estimating costs or planning work; others may involve highly technical details such as the composition of metals. But it is safe to say that an angineer who is thoroughly experienced in welding and cutting matters will be able to correctly direct the work or to call on additional advisers until the proper authorities have been consulted and the answer formulated.

It may be well to illustrate how certain problems have been handled. I will first take the case of welding submarine mines, which was undertaken as a very secret piece of work in the early days of the war. Oxy-acetylene welding was faund to make a thoroughly tight joint, but the light gauge metal warped to such an extent that the finished product was not considered satisfactory. Due to this condition of finished product, which was mostly one of appearance, oxy-acetylene welding was abandoned in favor of electric welding, but as the metal was of a very light gauge it was found difficult to make the electric welds tight to sea water, a highly important factor.

Before welding was tried on these containers, the submarine mine was made of two sections having rolled edges which fitted onto a rubber gasket. Clamps were placed over the rolled-up edges every few inches and these were then screwed tight so that the rubber would be properly compressed and theoretically watertight. It was found, however, that these mines were seldom tight, particularly in that tightness neant that not even a drop of salt water should enter the mine over a period of six months. About this time engineers who had had considerable experience in weld-

*Presented at the January 1923 Meeting, Philadelphia Section, A. W. S.

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ing problems were called in and jigs were developed which held the sheet metal so rigidly that warpage could not occur when the oxy-acetylene process was used. This resulted in the making of a thoroughly satisfactory weld for tightness and gave a symmetrical mine.

Now, after working out such problems, the engineers and operators who gained experience at that time were naturally in position to help on many other problems connected with proper handling of light gauge metal to prevent warping, etc., and the experience gained has been decidedly beneficial to all of us, because numerous other things are now done by welding that have grown out of the fact that welding engineers knew how to make essential jigs.

Another problem with which practically all of us are familiar is the welding of pressure vessels. It is interesting to see how this is being handled at the present time, because the final decision with regard to welding of pressure vessels will have a very distinct bearing on the advance of the entire welding industry.

The American Society of Mechanical Engineers became interested in the welding of unfired pressure vessels because the Society years ago had found it advantageous to get up a boiler code for the benefit of its members. As an outgrowth of the boiler code it was found desirable to get up a code for unfired pressure vessels. Codes of this kind are intended for one purpose only—specifying safe practices with regard to construction and safety devices to prevent applying excessive pressures to the vessels. A good many states have adopted the A. S. M. E. boiler code and the inspectors of boilers and pressure vessels in these states are, therefore, plainly interested in all of this new code work. Due to the failure of welded pressure vessels in several instances, State Inspectors wished to safeguard life and property in their respective states by forbidding the use of welding in such constructions. This would have been a serious blow to the welding industry, so it became a problem for the entire industry. It is being handled at the present time in a way which gives promise that a satisfactory solution will soon be reached, and it is to be noted that the welding engineers have been called in to help solve the problem.

It would be more difficult to handle problems of this nature if the companies selling welding equipment and supplies for welding were the only interested parties; but the manufacturers of pressure vessels have had so much experience with the welding processes that they are also back of the investigation work, even to the extent of contributing time and money to it. A committee of tank manufacturers was organized by the American Bureau of Welding which acts as the Welding Research Department of the American Welding Society and the National Research Council, to work on this problem because it was one of such wide scope that it affected a great many organizations. Seven members of this

committee contributed three welded pressure vessels and another twenty-one vessels, all of which were turned over to the Bureau of Standards for test. Many of the specifications of the American Welding Society, such as the composition of proper welding rods, have been incorporated into the tentative code and utilized in the welding on the test tanks.

Furthermore, many engineers who have been devoting a great deal of time to welding work, advised the committee of the A. S. M. E. with regard to test methods, until tests which it is believed will safeguard the user have been developed and are being used as the basis of testing the cylinders now in the hands of the Bureau of Standards. These tests which have been agreed upon resulted from observation of similar problems in various other industries; in other words the engineers were not in this case developing anything radically new, but were applying to the problem in one field the knowledge obtained in others.

The above history with reference to the problem of pressure vessels indicates the depth to which some problems may go, but even in the above I have not talked about the weldability of steel, or trying the proposed use of double "V" bevels on all edges of longitudinal seams on Class A tanks, or the design of tanks having heads concave to the pressure, etc., all of which points are having a very material bearing on the solution of the major problems, and which have been the outgrowth of constant study by the process engineers.

When the test results have been published, and the pressure vessel code has been established, we will have information which should be of great aid to one having similar problems with regard to the strength of, say, a pipe line weld. The welding engineers who have been working so faithfully on the problem will have, also a valuable experience to assist them in applying information thus obtained to new problems. With the growth of welding and pipe work who of us can fail to believe that we will not be swamped with scores of questions with regard to all types of welded pipe construction?

There are numerous other types of problems which affect the members of the Welding Society. A very common problem is that with regard to the effect of the cutting torch on steel. One of the first places where this problem attained real magnitude was in the Philadelphia District where, at the Navy Yard, turbine rotors were being cut from billets with the oxy-acetylene cutting torch at a great saving in expense over machining, but some of the discs showed cracks after the cutting operation and the Navy Department seriously considered forbidding the use of the oxy-acetylene cutting torch. Oxy-acetylene engineers were consulted by the Navy Yary officials and these engineers were able to point to the successful use of the cutting torch in several forge plants which were using the process for shaping up crankshafts, connecting

rods, etc., for assembly in heavy machinery requiring material of the very best construction. This lead deeply interested the officials of the Navy Department, who finally developed a procedure which has put the seal of approval on oxy-acetylene cutting, yet has safeguarded the operation by having the finished rotors annealed to relieve old strains.

It is safe to say that a gray iron casting which is broken or has sand-holes may be welded so as to have 100% of its original strength, provided it is properly preheated before the welding operation and is annealed thereafter. This is a broad statement which all of us should keep in mind. On the other hand we all know that thousands of broken gray iron castings are being thrown in the scrap heap every day, necessitating expensive replacement. It may be that the local job welder has not impressed the owner of the casting with his ability to weld it, or it may be that the owner has had experience with welding when correct preheating or annealing method was not followed, resulting in the repair being a failure; but whatever the reason, if anyone scraps a broken iron casting from now on it is because he does not call in an oxy-acetylene welding engineer to show him how the work can correctly be done.

On the business side we also have problems, such as how to estimate the cost for given work; what kind of tests to put on finished welds and, here again, the advice of engineers should be sought, because practically all who have submitted such problems have received satisfactory answers, with the result that the welding process is now being used in many places where it would not have been used if it had not been found possible to make satisfactory estimates and tests.

Some cases have recently come to hand in which the estimates of pipe welding costs have varied greatly. When the job is handled in one way, an estimate of, say, 70 cents will be given for the cost of an 8 inch welded joint, and $2.00 a joint when an entirely different method of handling work is involved. This difference is a very serious one, amounting to almost three to one, and it is, therefore, a real problem to all of us. Let us analyze this and see what additional information should be furnished so that we may know why the low cost is given in some cases and the higher cost in other cases.

We will take for example the 70 cents figure. This is based on actual welding labor, oxygen, acetylene and welding rod used in making one joint, basing the costs on gas delivered at, say, a fabricating shop such as might be found in one of the big pipe mills. A contractor who was laying a pipe line and who used this 70 cents figure as the cost of making a joint would be laying himself open to serious loss, because, first, his labor costs are more, due to the fact that the men have to be transported to and many times fed on the job, the gases have to be hauled out to the work,

and in addition to the actual welding we can well figure in the labor required for handling the pipe. On this basis the cost will be about $2.00 a joint on a well managed job. In between these two costs we find that of pipe welding in industrial centers, but where the work is done at some distance from a welding shop or central station. The labor costs will be the same for the actual welding as in the shop because local labor can be used. The gases will also be at a delivered price for the locality, no additional costs being required for distributing. But considerable extra help will be necessary for handling the pipe and this must be taken into consideration and so would make the cost, say, $1.25 or $1.50 per joint.

Calculation of costs does not stop, however, with the submitting of estimates of this kind. We find that the person who is requesting the information probably has never considered the cost of making a joint with a screw connection. Any fair comparison of costs must take account of these factors as on big installations a considerable saving can be made in the cost of pipe by using plain-end instead of threaded pipe, moreover, a lighter weight pipe can often be used, because there is no reduction in strength due to the threading. Again, 40 foot lengths of pipe can be used on pipe line projects where welded joints are made, whereas 20 foot lengths of pipe are used with the pipe laying machines. In addition to the above points we must consider that the cost of cutting off pipe with the ordinary mechanical cutting tool is a very heavy expense; then special vises and threading machines are required for threading the short lengths of pipe, which is seldom estimated in the cost of making the screwed joint. Our problem has, therefore, resolved itself into what does it actually cost to make a completed pipe system with the oxy-acetylene process and what are the comparative costs with the older method of threading or coupling? On top of the economic factor is, of course, the quality of the joint, and it is quite certain that all interested in the subject are convinced that the welded joint is much better than any other type of joint used in pipe work.

Another example of a problem which involves estimating is that which many have faced within the past year or two with regard to the cutting of steel in the scrapping of ships. It does not do to simply take a cutting cost table and say that this ought to be the cost of doing the job, because the cutting tables are primarily based on steady use of the torch under shop conditions. How does practice check with theory? As in the case of estimating the cost of welding a pipe line, we must consider among other things how much additional labor is required to do the entire job; how much of the job should be done with oxy-acetylene, and how much with the shears, etc.?

There are men in the country who have had a good deal of experience with cutting, men who have worked out these problems so that they are on a pretty sound basis. It is from these men

that the information should come, because it is based on actual accomplishment and gives inclusive costs. The engineers who are interested in oxy-acetylene cutting have had many problems of this nature put to them. One of the most interesting pertains to the cutting up of old railroad cars, wherein the contractor found that his costs were running very high and that his estimate for the contract was away out of line, yet his estimate had been made after consulting with an engineer who had quite exact information as to what the costs should be.

The contractor challanged the estimates which had been made as a result of the figures being obtained by him in practice, so an engineer was asked to study the actual work in operation for a few days and report on the work then in progress. He found that the operators were cutting as they found the work, taking everything as it came. This included the very light gauge metal on the sides of the cars and the heavy angles and reinforcing plates. He also found that the operators were quite unskilled, because the contractor believed that anyone could be taught to use a torch efficiently in a few days, and he could get inexperienced men at a much lower price than he would have to pay experienced cutters. The engineer then convinced the contractor that a good cutter is a skilled workman and that the quantity of gas used by him in the course of a day is worth two or three times his pay, and therefore, a man who can get the best out of the gases is worthy of his hire.

The contractor with the engineer's assistance then studied the problem from a managerial point of view and worked out the details of the cutting job so that skilled operators would cut first the line sections, using a minimum quantity of gas which would be sufficient on that type of plate, then going back over the heavy sections of the skeleton of the car, cutting them with a larger tip and the necessary gas pressures. In order to interest the men in their work he assigned a certain quantity of oxygen and acetylene for each unit of work and set up a basis of sharing in any savings of gas with the operator, but penalizing the operator if he used an excessive amount. This study of the car cutting costs resulted in the contractor's easily meeting the estimates which had been made as to the maximum for the job and, needless to say, the contractor was quite pleased.

It is certainly to be hoped that we will not find in a few years from now that present day users of the process have abandoned an application on account of minor difficulties when, by calling in engineers, the user would have received the necessary help and the problem have been classed among those solved to the satisfaction of all. We know that this has too often been the experience in the past and it is up to us to make sure that it does not occur in the future.

# ARC WELDING OF STEEL STRUCTURES*

F. P. McKIBBEN†

*Effect of Welding on Design.*

Steel structures may be classified as bridges, buildings, ships, and miscellaneous structures, the latter including tanks, towers, cars, etc. A brief review of the historical development of bridge construction is desirable, not only to point out important steps already taken in the art but to call attention to a new development now in its inception, but destined to exercise a very considerable influence on the design and fabrication of steel structures and probably also on costs. I refer to the substitution of electric arc welding for riveting, the latter being the common method by which steel members are connected together. While it is true that important changes in bridge building have been due largely to changes in the available materials, nevertheless some details of construction have exercised a very great influence on design, fabrication and erection of the major parts, and it may be that electric welding will in the near future be the next important step forward.

The influence of available materials can very readily be seen when one compares the stone arches of earlier days with the modern steel truss or with the modern reinforced concrete bridge. Stone being material which can carry compressive stresses is used only in structures of the arched type. Consequently the stone bridges of the Romans were entirely of the arch form, and the most notable of their structures existant is the Pont du Gard near Nismes in Southern France, which was built A. D. 19 and remains in use after nineteen centuries. On the other hand, steel capable of standing tensile as well as compressive stresses may be used in the form of an arch, a girder, or a truss, and the use within the past twenty-five years of concrete reinforced with steel rods has given us a new material, resulting in new designs for which this combination of steel and concrete is particularly adapted. It is thus seen that the material of which a bridge is built affects quite appreciably the type of the design, but what is of greater importance to us in the present discussion of arc welding is the influence which some of the details exert on the general design. For example, the first metallic bridges in the United States were built of wrought iron and the various truss members were articulated, that is, joined together, by a single cylindrical iron pin at each joint; and the idea prevailed throughout this country for several decades that such a pin connected truss was much better than a truss in which the various members were connected together at the joints by a group

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of rivets. In Europe the opposite view obtained and riveted trusses were about the only kind used. The use of pins or rivets at the joints makes a very great difference in the design of some of the main members, and consequently on shop practice and in erection.

Within the past six or seven years some steel structures have been built with neither pins nor rivets. The members were connected together by electric welding and this development in the art of steel construction is now making rapid progress. And if electric welding comes into extensive use it will undoubtedly not only change the design of the main members but will also very materially change shop practice as well as the final erection of bridges and buildings.

Structural engineers should now give careful attention to the application of electric welding to steel structures with the view of guiding the art along safe lines. Up to the present time most electrically welded structures have not been carefully proportioned with proper regard for the stresses to be carried and the strength of parts necessary to carry them.

## PRESENT PRACTICE IN STEEL BRIDGE CONSTRUCTION

*Quality of the Steel.*

Bridges and similar structures are made of structural steel for the main members and rivet steel for the rivets, all made by the Open Hearth process. The structural steel is soft but the rivet steel is softer. The following table shows the chemical and physical properties:

TABLE 1. PROPERTIES OF STRUCTURAL AND RIVET STEEL

| | *Structural Steel* | *Rivet Steel* |
|---|---|---|
| Phosphorus, maximum | | |
| Acid | .06 per cent | .04 per cent |
| Basic | .04 per cent | .04 per cent |
| Sulphur, maximum | .05 per cent | .045 per cent |
| Tensile strength, pounds, per sq. in. | 55,000 to 65,000 | 46,000 to 56,000 |
| Yield point, pounds per sq. in., minimum | 30,000 | 25,000 |
| Elongation in 8 in., minimum, per cent | 1,500,000 | 1,500,000 |
| | *Tensile Strength* | *Tensile Strength* |

Among the materials of construction structural steel exhibits remarkable uniformity in quality, and this, together with its softness, makes the process of welding by the electric arc a comparatively simple one.

*Types of Steel Structures.*

Buildings are either of the ordinary factory or mill building type with roof trusses resting on columns, or of the steel cage type

such as the tall office buildings so commonly seen in most American cities. Generally steel bridges are one of the two types, the plate girder or the truss. The plate girder consists of a vertical web plate with angles riveted horizontally lengthwise along the top and bottom edges of the plate with some horizontal cover plates riveted to the angles. As far as structures are concerned, practically all electric welding thus far accomplished has been confined to buildings or tanks. I do not recall any highway or railroad bridge fabricated with electric welding instead of rivets, but there is nothing inherently difficult about welding bridges by electricity. However, before the art is applied to bridge trusses, designs will have to be more carefully worked out than thus far has been the case in electrically welded buildings.

*Steps in Building a Steel Structure.*

The manufacturing process of constructing a bridge or a building consists of the following:

1. Design
2. Making the drawings.
3. Making templets
4. Marking steel
5. Punching or drilling holes.
6. Assembling.
7. Riveting.
8. Painting in the shop.
9. Erection
10. Painting in the field.

The determination of stresses and the design or proportion of the main sections and details for steel buildings and bridges have probably been as carefully developed as any type of engineering work. By far the greater part of stress determination is done by simple statics, but a very considerable number of structures are so complicated as to be statically indeterminate, in which case the theory of deflection must be used to determine the stresses. Heavy railroad bridges are designed to carry in addition to their own weight, two locomotives of the consolidation type with 60,000 lbs. on each pair of drivers. The two locomotives are followed by a uniform load representing the weight of a train. Highway bridges are usually designed for a uniformly distributed load representing a crowd of people, or for a steam road roller, or for an electric car, or a heavy automobile truck. The heaviest automobile truck of which I have any knowledge weighs 28,000 lbs., of which 21,000 lbs. are on the rear axle. In calculating stresses in highway bridges the various loads just mentioned are combined for some members to produce the maximum effect. For buildings, the loads used in addition to the dead weight consist of wind pressure and snow, together with uniformly distributed live load, representing a crowd of people or a quantity of merchandise.

After a bridge is designed shop drawings are prepared as shown by Fig. 1, which illustrates a small plate girder railroad bridge designed by one of my students. These shop drawings require a great deal of time and entail a large expense, for practically every dimension is indicated on the drawing, every rivet is carefully located, and the size, width and length of every structural shape is given. In the plate girder bridge shown in Fig. 1, there are 5,800 rivets. All of the rivets are shown on the drawing in such a manner that every piece of steel can be made separately.

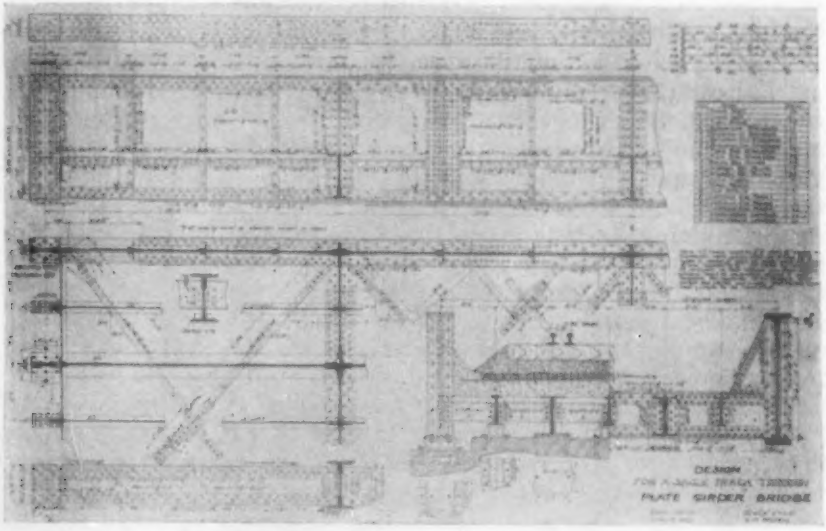



Fig. 1. Design for Plate Girder Railroad Bridge.

After the drawings are finished they are sent to the templet shop where full-sized templets made of wood or heavy leather board are prepared for each and every piece in such a way that all holes to be finally placed in the steel are indicated in position and size on the templets. These templets are then sent into the shop where they are clamped to the steel and each steel piece is marked to conform to its templet, both as to size, shape, and the location of all holes. These pieces of marked steel are then passed through shearing machines to shear them to shape and through punches to punch the holes. In most cases the holes are punched singly but the larger shops have multiple punches which can be used on some work and by which several holes are punched simultaneously. The numerous pieces, which make up a girder or other member and which have been cut to shape and punched, are now assembled and temporarily bolted together with a few bolts, all parts of two pieces of steel which are in contact having been previously given a coat of paint. These assembled members are

then taken to the riveting machines either fixed in position, in which case the piece to be riveted must be moved in order to bring the rivet in the proper position in the riveting machine, or the riveter is portable for use on heavy work and is so arranged that it can be moved about as the rivets are driven. Obviously in driving rivets it is frequently found that because of inaccuracies of workmanship holes do not come exactly opposite, but by driving a drift pin the holes are more nearly brought in line before the rivet is driven. Most of the holes in structural steel work are punched and after being assembled are then reamed to get a smoother and larger hole. On heavier materials or parts where the best results are desired holes are drilled.

The rivets are driven either by air or hydraulic pressure. Where air is used the pressure is generally from 85 to 100 pounds per square inch. Hydraulic pressure is used at 1.500 pounds per square inch, for the line pressure. The air or hydraulic pressure is transmitted through a piston, thence multiplied and applied to the rivet; the rivet having been previously heated to a red heat. The process of riveting consists therefore of placing through the holes the red hot rivet with a head on one end. As the pressure is applied the head is formed on the other end and the material in the shank or cylindrical part of the rivet is upset and pressed into the holes in the steel parts. If the rivet is too cold, or the thickness of steel to be riveted is too great, or the pressure on the riveting machine is not sufficient the rivet is not upset enough to fill the hole, and proper bearing of the rivet upon the plate is not secured. Now as these rivets cool they contract and draw the various steel pieces very tightly together, but in electric welding there is nothing quite corresponding to this action so that in structures thus far electrically welded various kinds of clamps are restored to for holding the pieces together.

After the steel member has been thus completely riveted it is given one coat of paint in the shop, and another coat is applied after erection in the field.

When the finished members leave the shop for erection at the bridge or building site they are provided with open holes at the joints, into which after erection rivets are driven either by hand or power. Frequently in the construction of buildings, bolts instead of rivets are used in the field connections.

Until recently, rivets have been heated in coal, coke or oil heaters only, but electric rivet heaters are now being used to a considerable extent. A recent test indicates that it costs $.70 to heat 100 lbs. of rivets in a coal furnace and $.40 per 100 lbs. to heat them with electric heaters, the price of current being $.02 per KW hour. With electric heaters there are practically no burned rivets. This is due largely to the individual heating of the rivets and because the rivet is constantly in plain sight of the operator, which is not the case when oil, coke or coal is used for fuel. In case of

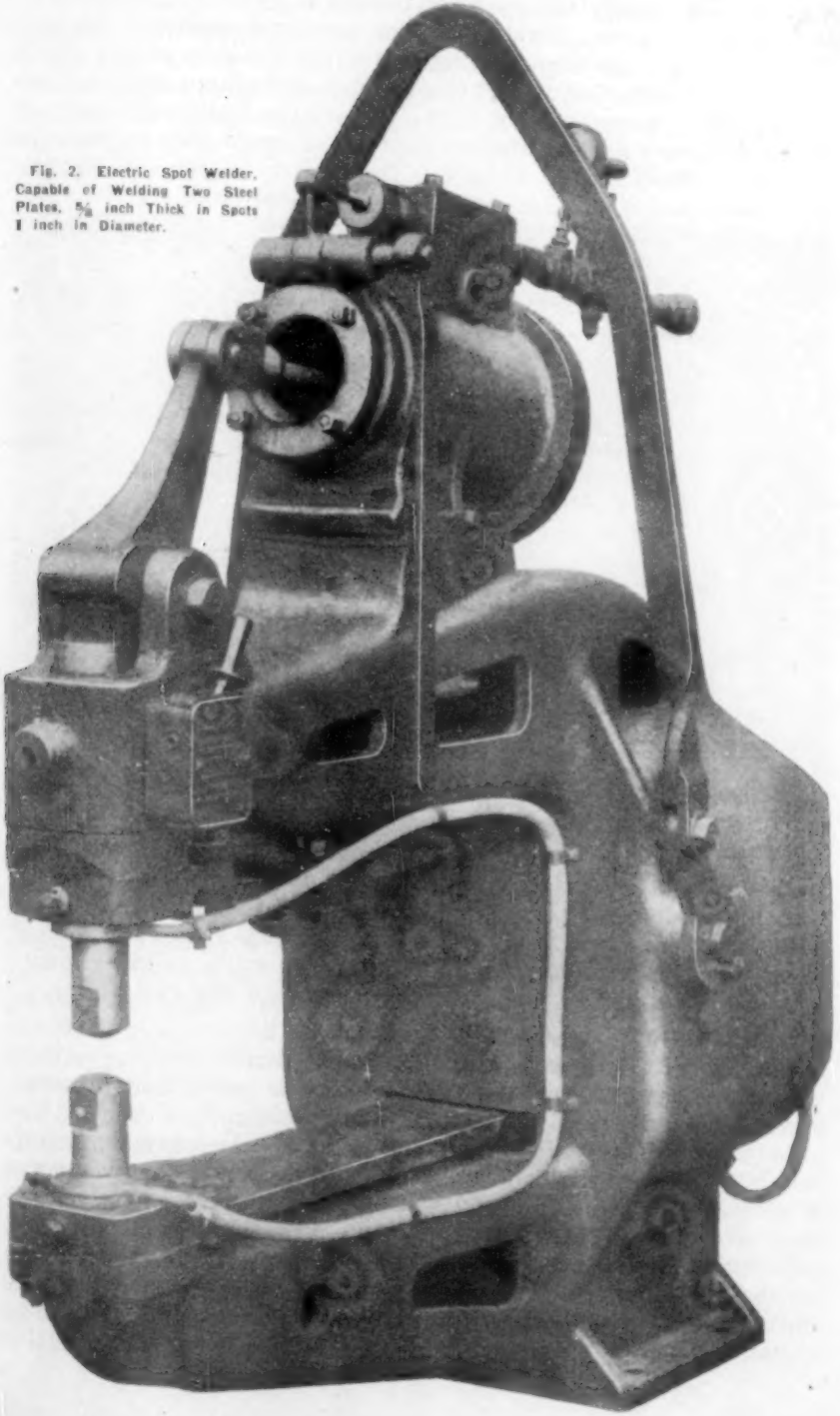


Fig. 2. Electric Spot Welder, Capable of Welding Two Steel Plates, 5/8 inch Thick in Spots 1 inch in Diameter.

coal or coke usually the operator throws a shovelfull of rivets in the forge and a considerable number are overheated and burned. The "American Machinist" investigated the quantity of lost rivets in various plants throughout the country and stated that the loss amounted to approximately 15%. In a large industrial plant of which I have some knowledge, the loss of rivets due to burning in coal forges is from 7 to 10%. The electric heater also has the advantage that smoke and gases are eliminated from the shop and there is no coal and ashes to be handled.

## THE WELDING OF STEEL

There are at present three important methods in use for uniting two or more pieces of steel; first, riveting which has been described above; second, gas welding; and third, electric welding.

In the gas welding process an oxy-acetylene flame is directed upon the two pieces of steel to be joined together while the end of a filling rod, or wire of steel, is applied to the heated zone, fusion takes place and the two pieces of steel are united in this manner. The operator holds the oxy-acetylene torch in one hand and the filling rod in the other.

Electric welding may be divided into two types—resistance welding, and arc welding.

*Resistance Welding.*

In resistance welding the two surfaces to be united are brought in contact, a current is passed from one to the other, heating the junction, and the two pieces of steel are then pressed together. This process obviously is very similar to blacksmith welding. But the most common form of resistance welding thus far employed is spot welding, which has been frequently used to unite steel plates in much the same manner as by rivets. (Fig. 2). In spot welding two steel sheets to be connected are placed between electrodes which force the plates together under a heavy pressure. Current is then turned on, the plates are brought to a welding heat, which together with the pressure causes a spot weld, that is, a union of the two plates in the form of a small cylinder which in the process has become an integral part of the two plates.

*Arc Welding.*

But by far the greatest application of electric welding now in use is arc welding and this process can be subdivided into two parts, carbon-arc welding and metal-arc welding.

In carbon-arc welding an arc is formed between a carbon or graphite electrode fixed in an insulated holder and the two pieces of steel which are to be welded. The arc is formed by touching the carbon electrode to the steel plate and then withdrawing it a short distance from the plate. Into this arc is held a welding rod, which in fusing unites with the two pieces of steel. Obviously oxy-acetylene welding and carbon-arc welding are quite similar in operation.

In metal-arc welding the welding wire or rod is one electrode and the steel to be welded is the other. It is thus seen that in metal-arc welding the filling rod replaces as the electrode, the carbon or graphite electrode of the carbon-arc process. In metal-arc welding the filling rod or wire, which is fixed in an insulated holder, melts and is fused with the molten steel of the parts to be welded.

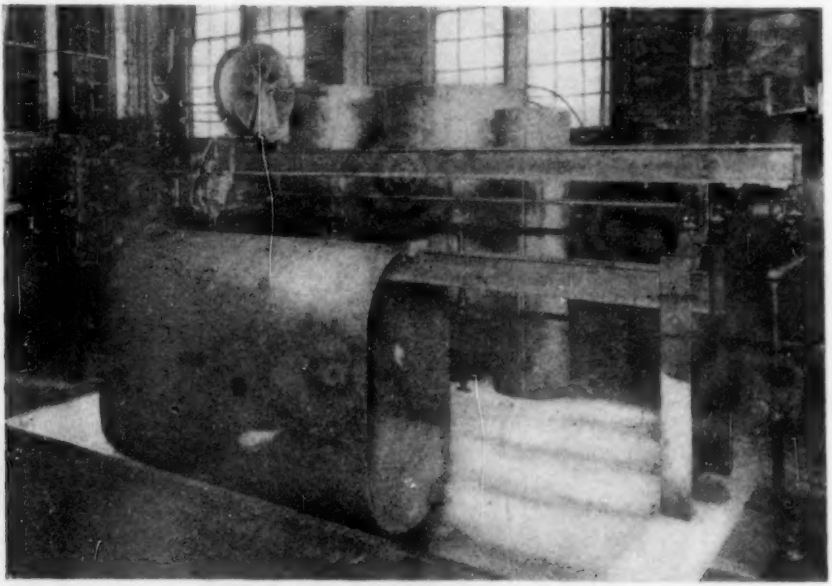


Fig. 3. Tank in Position Ready for Welding by Automatic Arc Welder.

For electric arc welding either direct or alternating current can be used, the kind of current varying with the requirements; generally, however, direct current is used for steel structures. In metal arc welding with bare wires the electrode is generally connected to the negative terminal and the steel to be welded to the positive terminal. But when flux covered electrodes are used they are usually connected to the positive terminal. The current for welding ordinary thickness of structural steel, say up to ½ inch, varies from 100 to 150 amperes but higher values give better results. The welding of practically all steel structures of any size thus far welded has been done by hand, but several companies have on the market automatic welding machines which give good results on repetition work, such as tanks where the welding is performed in one long line. It is probable that as electric welding of bridges develops, automatic machines will be used in welding long members, such as plate girders and built up sections for truss members where long plates and angles are welded together. (See Fig. 3).

Electrodes vary in diameter from one-eighth of an inch up to one-quarter of an inch; some are merely bare wire and others are covered with a flux; some are particularly pure iron; others have large and some have small percentages of carbon and manganese with smaller percentages of phosphorus, sulphur and silicon. On account of oxidation which occurs when the fused metal is being deposited in the weld, flux covered welding wires are being used in order that the coating on the surface of the wire electrode may form a flux to prevent oxidation by excluding the air from the fused metal. However, tests do not seem to indicate a great superiority, either for bare, or for flux covered electrodes.

In the present state of arc welding the skill of the welder plays such an important part that proper training is essential before any workman should be permitted to weld any structure of vital importance. Apparently a good welder cannot be produced without several months of careful training, but with skill once acquired very uniform results are produced on structural steel. All parts of the workman's body should be protected against the electric arc to prevent burning of eyes and skin.

The statement is frequently made that it is impossible to inspect the quantity of the work done in electric welding but that in riveted work the strength of the rivets can be ascertained by ordinary inspection. Rivets are inspected by tapping the heads with a hammer in such a way that looseness is at once detected by sound or motion of the rivet head, indicating that the rivet has not been properly upset and does not fill the hole. But even if this be the case and motion of the joint later takes place, the rivet will be of value in carrying stress, so that mere ordinary looseness of a rivet does not necessarily signify a dangerously weak joint. Moreover, many of us who have inspected rivets realize that there are several tricks by which a loose rivet can be made apparently tight without in reality being so. Apparently the method of inspecting a welded joint is by examination of the continuity of the deposited metal. for it is found that when the arc is broken a poor place in the weld is apt to occur. At times cracks can be detected in the deposited metal, or bead, as it is commonly called. Moreover the size of the bead should be observed, for smaller beads usually indicate greater strength.

## TEST DATA ON ARC WELDING

In studying the strength of electric welds it is unfortunate from the structural engineer's point of view that practically all of the tests have been made from specimens cut from butt welds and tested in pure tension. For comparative purposes in ascertaining the relative values of varying amounts of current, varying composition of electrodes, different polarities, etc., tension tests are of great value. But at the present stage of the application of arc welding to steel structures we are more in need of experimental data on the shearing strength of electrically welded joints rather

than their tensile strength. Practically all riveted joints depend for their strength upon the shearing value of the rivets or on the bearing of rivets upon plates connected, and as it is comparatively easy to substitute electric welding for rivets in many structures without materially changing the present standard forms for steel members, the deposited metal at the weld will be subjected to shearing rather than to tensile stresses. The best data thus far published on shearing strength of deposited metal are those of E. S. Humphrys, Jr., made at the General Electric Company's Schenectady plant and at Union College, published in "Iron Age,"

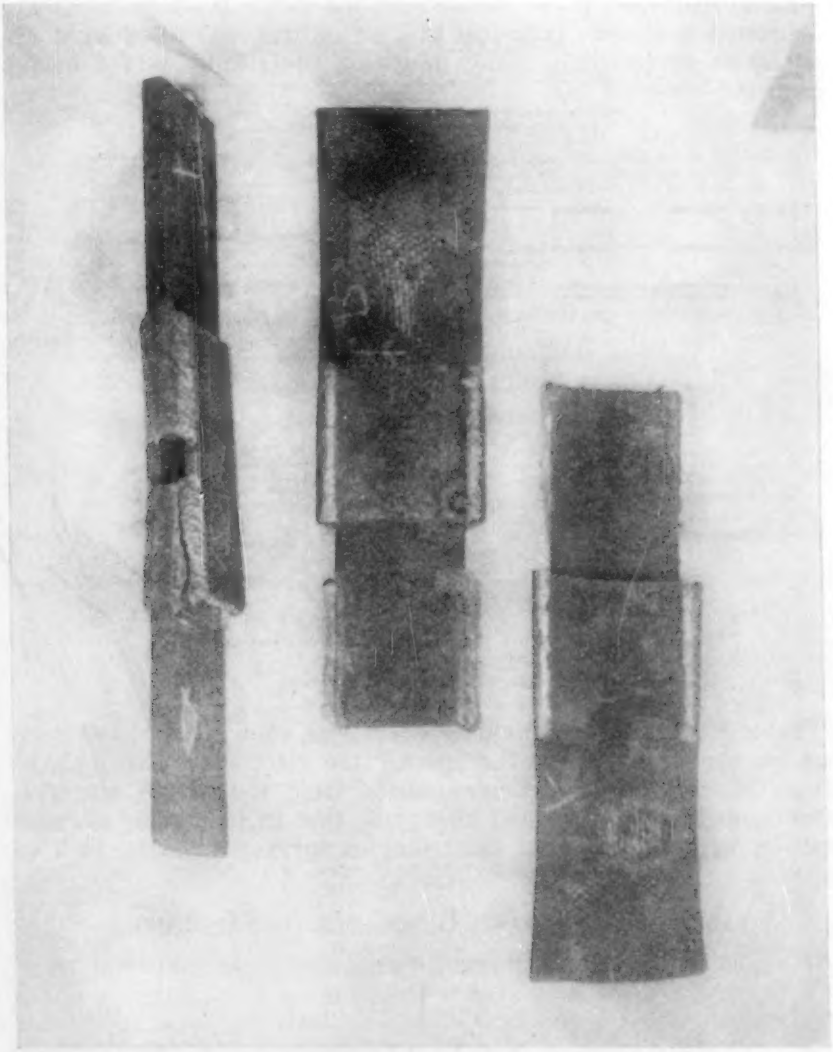


Fig. 4. Two Test Specimens After Being Tested. Middle and left pieces are two parts of one broken specimen. The right specimen shows the shearing of the bead.

May 25, 1922. The accompanying figures and tables give the results of these tests, which mark such a step forward as to merit some attention. Referring to Figs. 4 and 5 it is seen that each specimen consists of two plates joined together by two splice plates in such a manner that the deposited metal, or beads, runs parallel to the length of the plates and therefore parallel to the tensile pull exerted upon these plates, with the result that the beads are subjected to shear. It is just this action that will be brought upon beads deposited in many joints of electrically welded bridge and roof trusses.

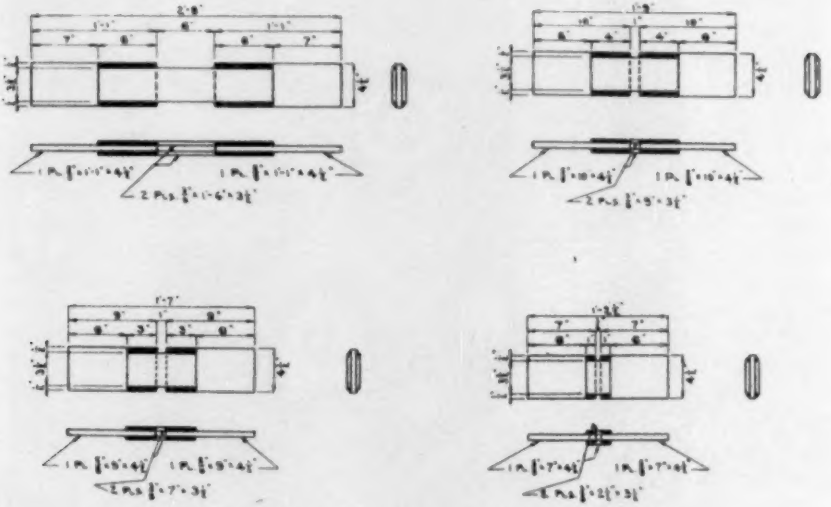


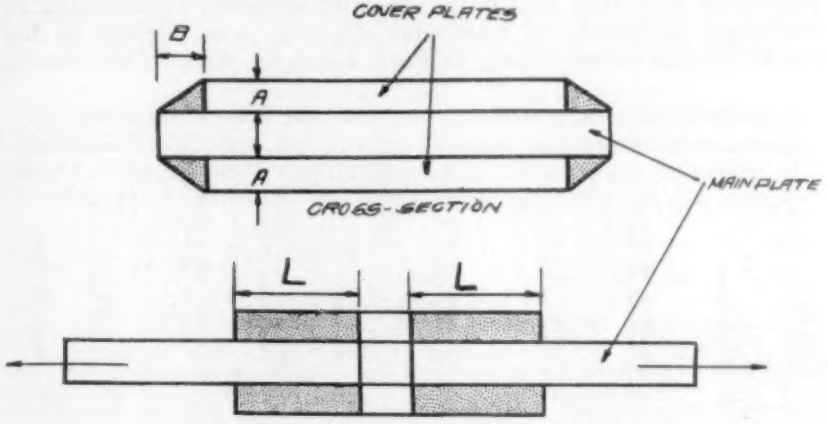
Fig. 5. Details of Test Specimens.

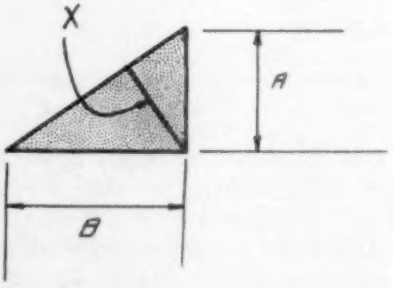
Table No. 2 gives the welding operations showing that the voltage at the arc was 20, the size of the electrode, 5/32 inch in diameter, and that the current varied from 150 to 175 amperes. The beads were of the usual fillet type; that is, triangular in cross section with the bases of the triangles varying from ¼ inch to ½ inch.

TABLE 2. WELDING OPERATIONS FOR TEST SPECIMENS

| | | *ELECTRODE* | | | *TIME* | |
|---|---|---|---|---|---|---|
| Test No. | Arc Volts | Size In. | Amount (Each Spec.) Lb. | Amperes | Total Min. | Rate (Lineal In. per Min.) |
| 8 | 20 | 5/32 | 1.39 | 175 | 33.00 | 0.73 |
| 6 | 20 | 5/32 | 0.966 | 175 | 19.87 | 1.22 |
| 9 | 20 | 5/32 | 0.77 | 150 | 22.75 | 1.06 |
| 10 | 20 | 5/32 | 0.551 | 150 | 14.25 | 1.686 |
| 11 | 20 | 5/32 | 0.328 | 150 | 9.00 | 2.67 |

Table No. 3 shows that the shearing strength of the bead varies form 31,145 lbs per square inch for the ½ inch bead to 42,000 lbs. per square inch for the ¼ inch bead, and the table shows quite conclusively that the smaller the bead the greater is the unit shearing strength in pounds per square inch. It should be pointed out




DETAILS OF TEST SPECIMEN

Fig. 6.

here that when these specimens failed in the testing machine the plane of fracture, i. e., plane of shear, was not the base of the triangular fillet but was on a plane extending from the apex of the triangle perpendicularly to the hypothenuse opposite the plane of smallest shearing area. The plates were of ordinary structural steel quality and the electrode was a standard commercial bare wire, high in manganese and low in carbon, sulphur, phosphorus and silicon. The average shearing strength of the beads for all

specimens which failed by shear was 36310 lbs. per square inch.

Table No. 3 shows that in test specimen No. 3 the length (L) of the bead was so large that failure occurred by tension in the main plates and not by the failure of the weld. On all other specimens shown in Table No. 3 however, the length (L) of the bead was made such that failure of the joint occurred by shearing of the beads on planes of minimum shearing area parallel to the line of pull as shown clearly in Figs. 4 and 6. Each of the results

TABLE No. 3. SUMMARY OF TESTS ON WELDED PLATES

| Test No. | Ultimate Load—Pounds | Minimum Net Area of Plates—Square inches | Tension Net Area Pounds per Square Inch | Dimensions of bead—Inches A x B x L | Maximum Width of Bead—Inches | Minimum Shear Area of Bead—Square Inches | Maximum Shear in Bead Pounds per Square Inches | Shear per Lin. Inch of Bead | Method of Failure |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 3 | 158420 | 2.625 | 60350 | 3/8x1/2x6 | 3/10 | 7.2 | 22000 | 6600 | tension in plate |
| 4 | 149500 | 2.625 | 57000 | 3/8x1/2x4 | 3/10 | 4.8 | 31145 | 9340 | shear in bead |
| 5 | 116320 | 2.625 | 44310 | 3/8x1/2x3 | 3/10 | 3.6 | 32310 | 9693 | " |
| 5A | 45570 | 2.625 | 17360 | 3/8x1/2x1 | 3/10 | 1.2 | 37980 | 11390 | " |
| 8 | 142500 | 3.00 | 47500 | 1/2x1/2x3 | .355 | 4.26 | 33400 | 11875 | " |
| 6 | 131110 | 2.625 | 50000 | 3/8x1/2x3 | 3/10 | 3.6 | 36500 | 10926 | " |
| 9 | 120000 | 2.625 | 45700 | 3/8x3/8x3 | .266 | 3.19 | 37650 | 10000 | " |
| 10 | 96400 | 1.750 | 55100 | 1/4x3/8x3 | .209 | 2.44 | 39500 | 8033 | " |
| 11 | 89650 | 1.750 | 51100 | 1/4x1/4x3 | .177 | 2.13 | 42000 | 7470 | " |
| | | | AVERAGE | | | | 36310 | 9840 | |

Column (4) = (2) : (3); (6) = x (see Fig. 6); (7) = 4L x (6); (8) = (2) : (7); (9) = (2) : 4L.

TABLE 4. SAFE ALLOWABLE SHEARING STRENGTH FOR BEADS AT 9,000 POUNDS PER SQUARE INCH

| A | B | X | Safe strength per linear inch of bead |
|---|---|---|---|
| in. | in. | in. | lbs. |
| 1/2 | 1/2 | 0.355 | 3195 |
| 3/8 | 1/2 | 0.300 | 2700 |
| 3/8 | 3/8 | 0.266 | 2394 |
| 1/4 | 3/8 | 0.203 | 1827 |
| 1/4 | 1/4 | 0.177 | 1593 |

given in Table No. 3 is the average of the results of four test specimens. For example, the result of 142,500 lbs. as the breaking load for test No. 8 is the average of the four following tests: 146170; 139580; 149990; 134250. The maximum variation from the mean in these four tests is about 5.3% while for specimen No. 6 with an average breaking load of 131,110 lbs. the maximum variation in the four specimens making up this average was about 1%. These results show remarkable uniformity in the workmanship.

Column 8, Table No. 3, giving the average shearing strength of bead at 36,310 lbs. per square inch, is the ultimate shearing strength, that is, the breaking strength. If a factor of safety of four be applied, the safe allowable shearing strength per square

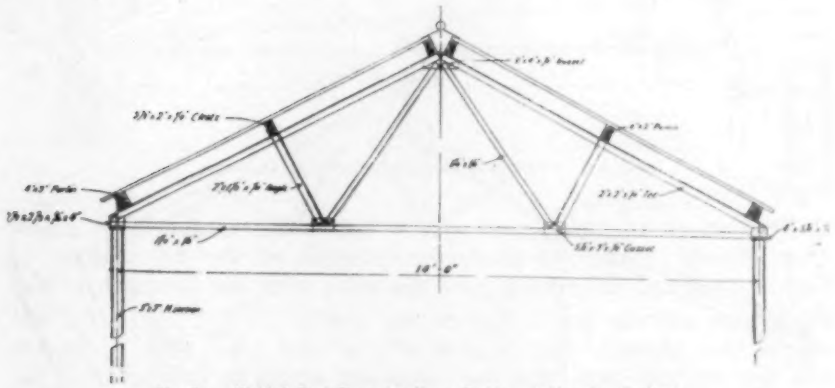


Fig. 7. Welded Roof Truss for Horse Stable at Olympia, England.

inch of longitudinal section of bead on the minimum section is approximately 9,000 lbs per square inch. Using this value, Table No. 4 shows the allowable safe working stresses in lbs. per linear inch of bead for beads of varying dimensions. For example, for a triangular bead ½ inch deep by ½ inch horizontally the minimum shearing section would be 0.355 square inches, which multiplied by 9,000 lbs. per square inch, the safe working shearing strength, gives 3,195 lbs per liear inch of bead.

It is evident from Table No. 3 that for conditions under which these tests were carried out a bead length of 6 inches (L) is longer than is necessary to develop the ultimate strength of the steel plates for in test No. 3 the plates broke in two and the welds held intact, whereas in all other tests having length of bead (L), 4 inches or less, the weld sheared along the beads. The plates did not break. A length of bead (L) can be computed in such a way as to make the strength of the weld equal to the strength of the main

plates in tension. It is like this: assuming net area of main plates to be equal to or less than the net area of the splice plates; let S = ultimate tensile strength of main plates in pounds per square inch of net cross-section; b = the shearing strength of the one bead per linear inch. The ultimate tensile strength of the main plate is equal

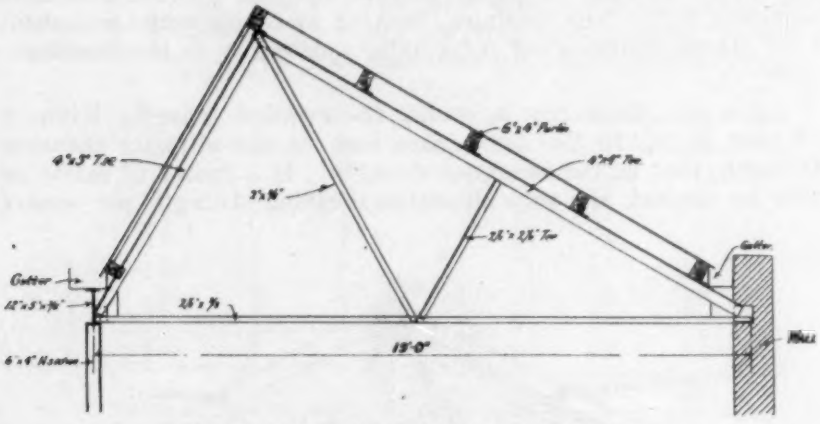



Fig. 8. Welded Roof Truss for Stelfast Works at Brixton.

to Stw where t = thickness and w the width of the main plate. (See Fig 6). And the shearing strength of the four beads = 4 bL. Equating the strength of the plate with the strength of the beads and solving for L the results are $L = \frac{Stw}{4b}$. If, for example, the ultimate tensile strength of the steel (S) = 60,000 lbs. per square inch and the ultimate strength of the bead be 9,840 lbs. per linear inch, then L = 1.5 tw. If the thickness (t) and width (w) of each main plate be $\frac{5}{8}$ inch and $4\frac{1}{2}$ inch respectively, as was the case in these tests, then length of bead (L) to give equality between tensile strength of plates and shearing strength of beads is equal to 4.3 inches. Evidently then any of the above specimens with L greater than 4.3 inches should result in breaking the main plate in two and any specimen in which L is less than 4.3 inches would result in shearing of the weld.

It should be borne in mind that the above study is based on the average shearing strength of bead per linear inch.

Let us look a little further into this matter of the strength of the bead. The ultimate tensile strength of one main plate equals Stw. The ultimate shearing strength of the four beads each of length L = 4 LXv. Refer to Fig 6. Where v = ultimate shearing strength in pounds per square inch of the bead on minimum longitudinal section at X. But $X = \frac{AB}{\sqrt{A^2 + B^2}}$ and hense the shearing strength of the four beads $= \frac{4\,LABv}{\sqrt{A^2 + B^2}}$. Equating the

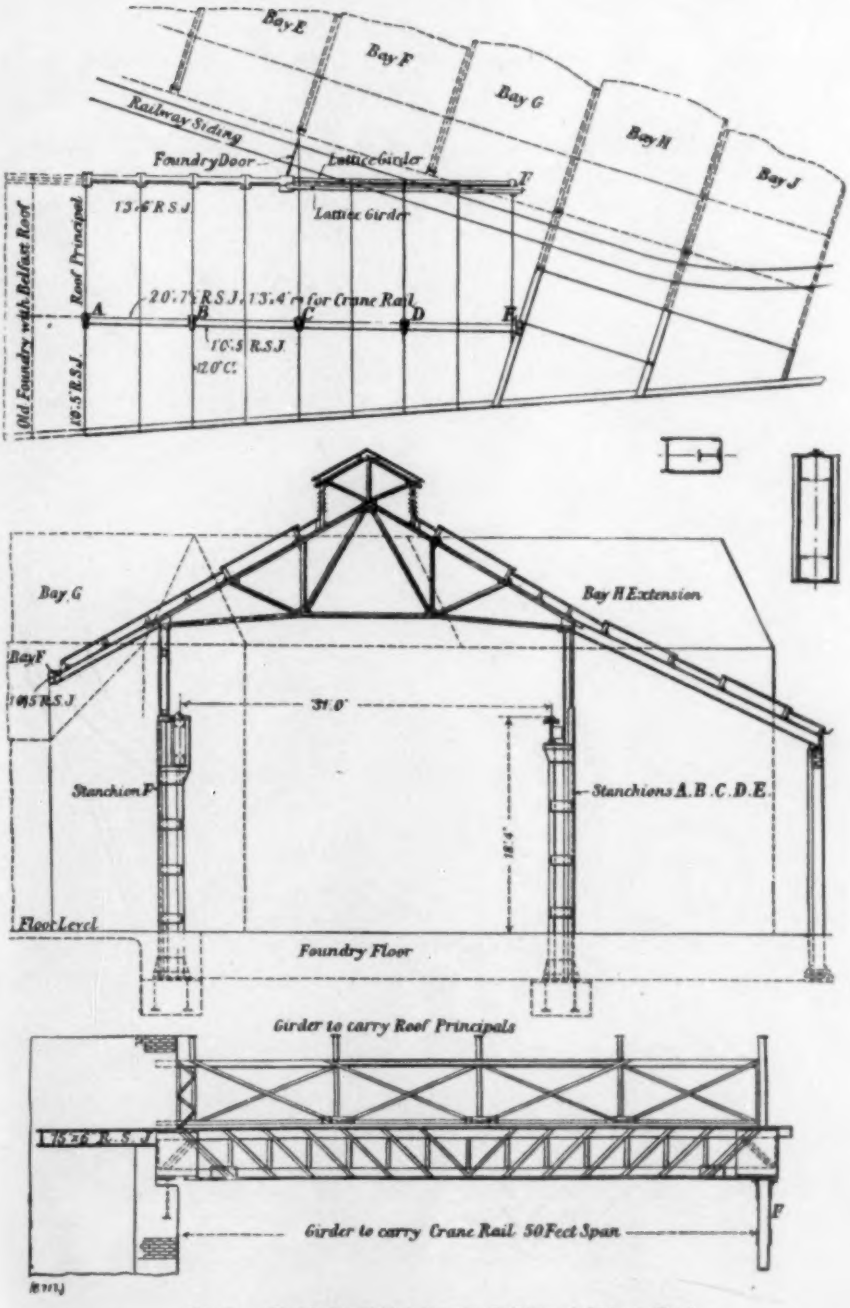



Fig. 9. Electrically Welded Foundry Building at Stoke-on-Trent.

strength of the plate to the strength of the beads and solving, length $L = \frac{Stw\sqrt{A^2+B^2}}{4ABv}$ Where $B = A$ $L = \frac{.35\ Stw}{Av}$.
When $S = 60{,}000$ lbs per square inch and $v = 36{,}000$ lbs. per square inch $L = \frac{.58\ tw}{A}$.

Physical tests show conclusively that to secure good welds, beads should be laid in thin layers lengthwise of the line of stress and that successive layers should be applied only to clean surfaces which may be cleaned fairly well by a wire brush, but the sand blast seems to give better results.

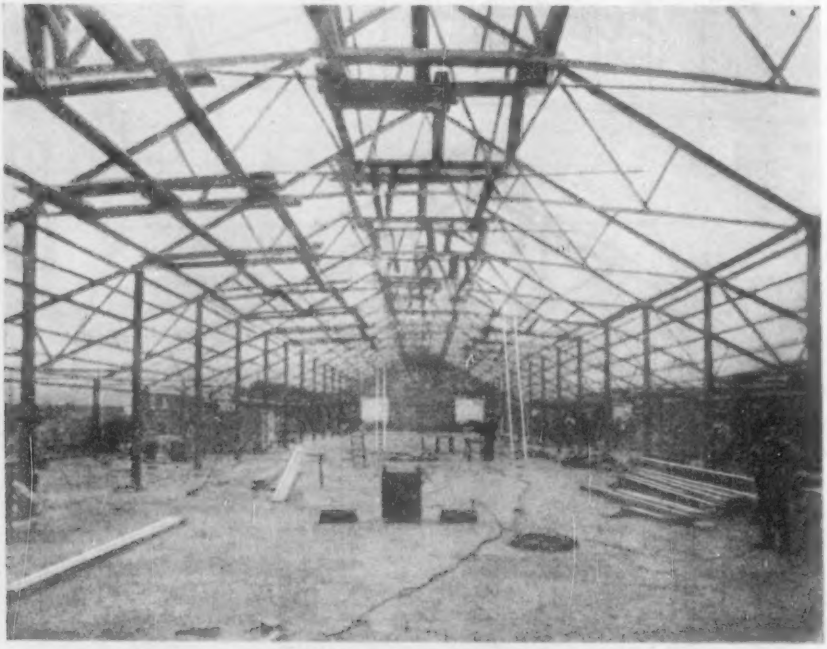


Fig. 10. Electrically Welded Building at Gottenham, London, England.

EXAMPLES OF ELECTRICALLY WELDED STEEL STRUCTURES

Following is a list of the more important steel structures which have been welded by the electric arc:

| | Fig. No. |
|---|---|
| Stables for the Olympia Horse Show, England (1920) . . | 7 |
| Mill building at Brixton, S. W. England . . . . . | 8 |
| Extension to foundry, Stoke-on-Trent, England (1920) | 9 |
| Steel mill building with 40 foot span central trusses and 2 wing bays 15 feet wide, Tottenham, London . . . . | 10 |

Cross channel barge—length 125 feet, 9 inches—breadth 16 feet, 4 inches—molded depth, 7 feet, 9 inches. Built in England about 1918.....
500 ton coasting ship Fullagar—launched February 5, 1920 ..... 11
Transmission line towers in Belgium.....
Reconstructed gas holders at South Melbourne, Australia
New roof on gas holder at Fitzroy, Australia.....
New gas holder 200 feet in diameter at Melbourne, Australia ..... 12
Material shed in Brooklyn, New York..... 13-16
A derrick boom, 90 feet long in America..... 17
Gondola freight car—50 ton capacity.....
Oil storage tank—40 feet diameter, 20 feet high—Muskogee, Oklahoma.....
Oil storage tanks—15 feet diameter, 16 feet high—Muskogee, Oklahoma.....
Transformer tower—General Electric Co., Schenectady, New York..... 18-19
Bridge connecting two buildings—General Electric Co., Schenectady, New York..... 20
Annealing cart—General Electric Co., Schenectady, New York ..... 21

The following is a brief description of the above structures:

Fig. 7 shows a steel frame for stables at Olympia, England, built in 1920 by the Welded Construction Company. The building covers an area of over 9,000 square feet, the span of the roof trusses being 14 feet. All steel parts were cut to length and delivered to the site of the building ready for erection, where two welders and four laborers obtained an output of 10 completed trusses per day. The drawing shows tension members to be flat bars 1¼ inch x ¼ inch. My experience has been that such small bars are difficult to keep straight during transportation or erection. Angles or structural shapes are better. The same company constructed at Brixton, S. W., England, Fig. 8, a mill building with a sawtooth roof covering 22,000 square feet, having roof trusses of 3 spans each of 19 feet, and supported on H section columns. Truss members were cut to proper lengths and then placed in jigs, where they were held in position and the joints welded. The truss was then removed and erected.

The Welded Construction Company built in 1920 at Stoke-on Trent, Fig. 9 an extension of a foundry approximately 100 feet long by 54 feet wide, the main span of the roof trusses being approximately 35 feet with two side spans. One of the interesting features of this construction is a latticed girder on the 50 foot span carrying some roof trusses and a traveling crane.

The Welded Construction Company also built a mill building for the Galvanizing Equipment Company, Ltd., at Tottenham, London, Fig. 10, the central span of the roof truss being 40 feet with two side spans each 15 feet. No rivets or bolts were used in any of the above structures.

In 1917, for use between England and France, a cross channel barge was built, in which riveting was entirely replaced by electric welding, the length being 125 feet 9 inches, breadth 16 feet 4 inches, molded depth 7 feet 9 inches. The shell plating was ¼ inch and 5-16 inch, lapped and joggled. The plates were assembled by means of a few service bolts, which after the welding of the joints were withdrawn and the holes closed by means of arc welding. Several barges of this type have been built in England.

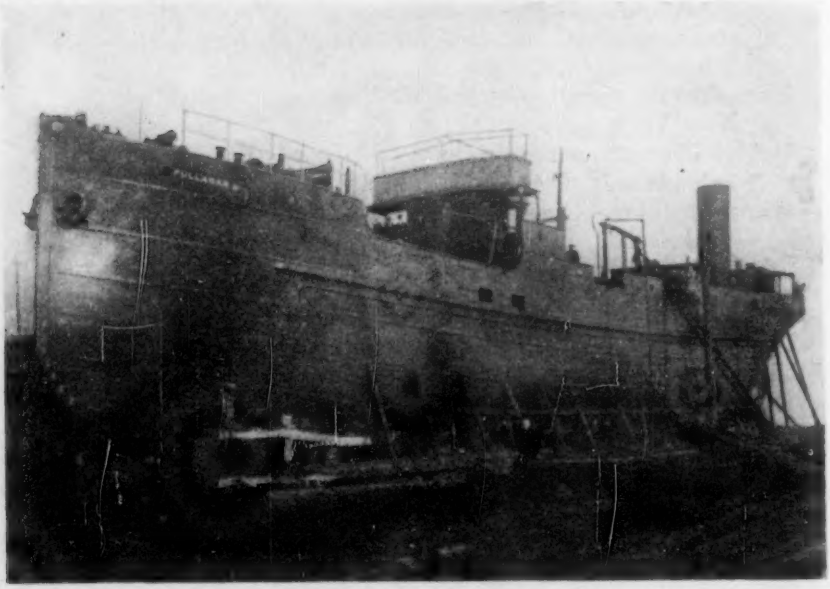


Fig. 11. Electrically Welded Ship Fullagar, built by Cammell Laird and Company, Birkenhead.

On February 5, 1920 the 500 ton coasting ship Fullagar with a length of 150 feet was launched at Birkinhead, England, all parts being arc welded. Fig. 11.

Transmission line towers have been constructed in Belgium with a height of 72 feet, carrying 7 wires on 525 foot spans. All parts were electrically welded except for convenience in transportation the upper and lower sections were spliced together in the field with bolted joints.

The Metropolitan Gas Company of Melbourne, Australia in 1920 reconstructed a gas holder at South Melbourne and a very considerable amount of the material was connected by electric welding

in place of rivets. This gas holder has a capacity of 3,000,000 cubic feet and consists of 3 lifts with diameters of 191 feet 6 inches, 194 feet 6 inches, 197 feet 6 inches. The holder contains 600 tons of material. The same company applied electric welding to a gas holder at Fitzroy where a new roof electrically welded has been constructed over the old leaky riveted dome while the holder was still in use. The new roof was welded in sections upon the ground, erected in place and the sections welded together. The diameter of the roof is 130 feet. At Fitsroy the same company has completed a new gas holder of 2,000,000 cubic feet capacity, which except for the assembly rivets is electrically welded. The

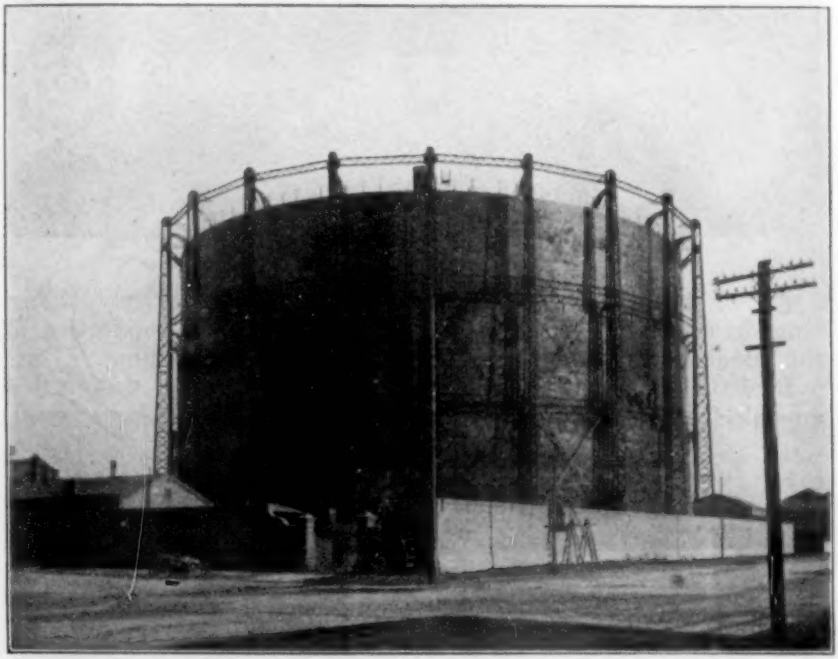


Fig. 12. Gas Tank, 200 Feet in Diameter, Electrically Welded, Melbourne, Australia.

diameter of the tank is 150 feet and has four 35 feet lifts. The latticed guide columns are 130 feet high. Still another tank 200 feet in diameter was constructed in Melbourne, Australia.

The Electric Welding Company of America built in 1920 a material shed, in which no rivets were used, all parts being arc welded from current supplied by a generator driven by a gas engine. This structure was tested by the Department of Buildings, City of New York, on a span of 49 feet, with 48 short tons of test load applied to each truss for two days. Figs. 13 to 16.

Fig. 16 shows an electrically welded supporting bracket for a crane runway.

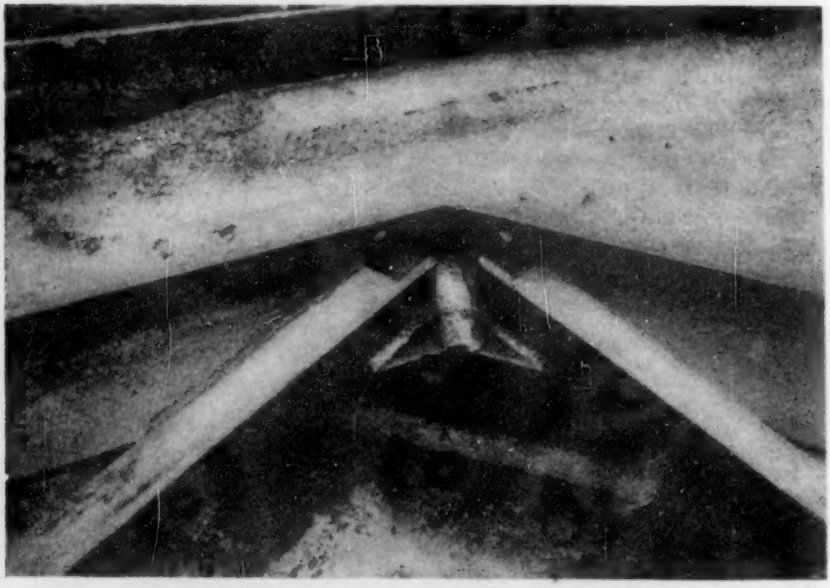


Fig. 13. Peak of Electrically Welded Roof Truss of Factory Building.

Fig 17 shows a large boom for a derrick, approximately 90 feet long, in service at the present time. Except for a connection at the middle of the boom, all joints are made by arc welding.

In 1911 the American Car & Foundry Company designed a gondola freight car of 50 tons capacity, in which electric spot weld-

Fig. 14. Test of Electrically Welded Roof Truss of Factory Building.

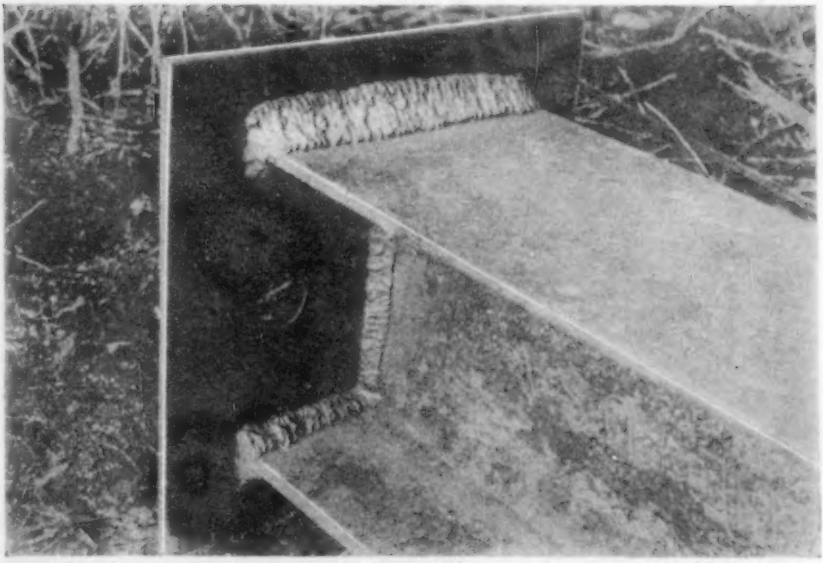
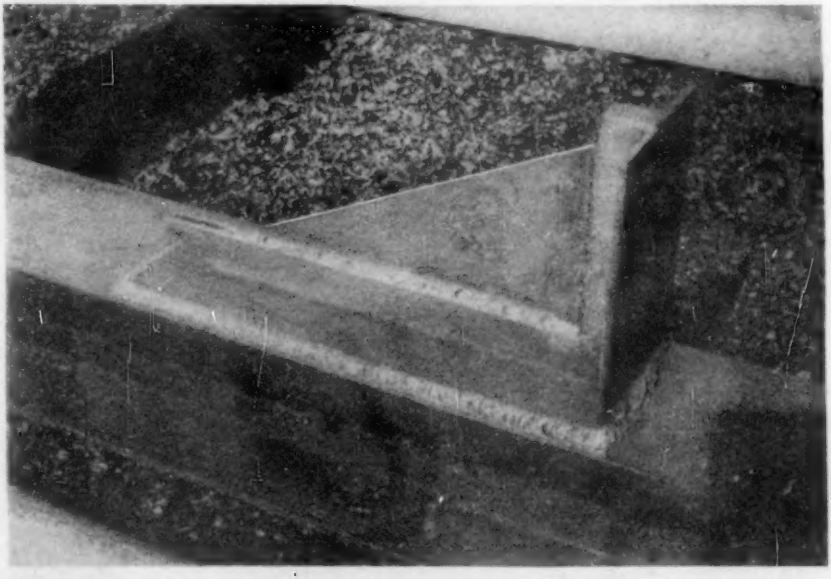


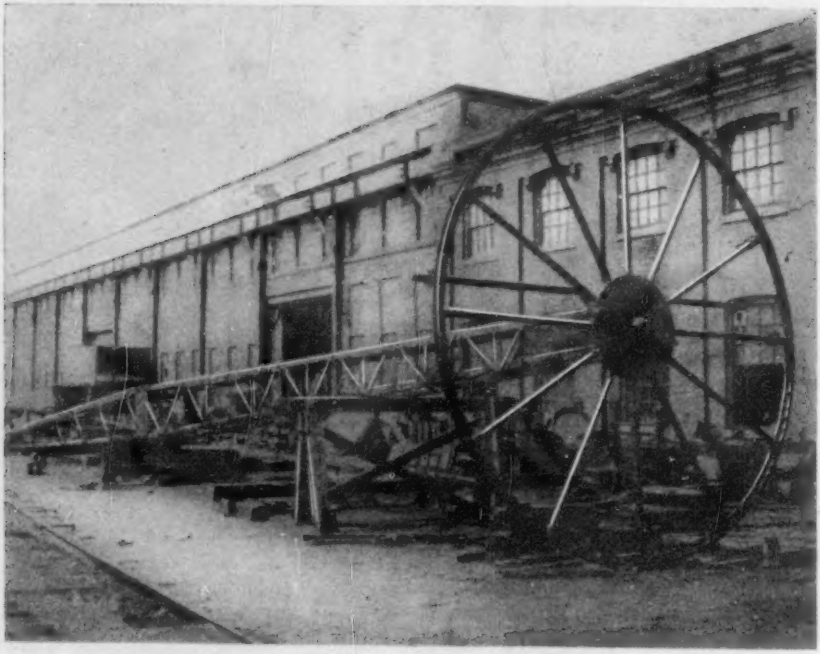
Fig. 15. Base Plate Electrically Welded to Column for Factory Building.

ing was used in the superstructure. The car was finished in 1911 for the Chicago & Burlington & Quincy Railroad.

In October 1920 the Electric Welding Company of America finished for the Oklahoma Producing & Refining Corporation at



ig. 16. Side View of Supporting Bracket for Crane Runway Electrically Welded to Column of Frame Work for Factory Building.



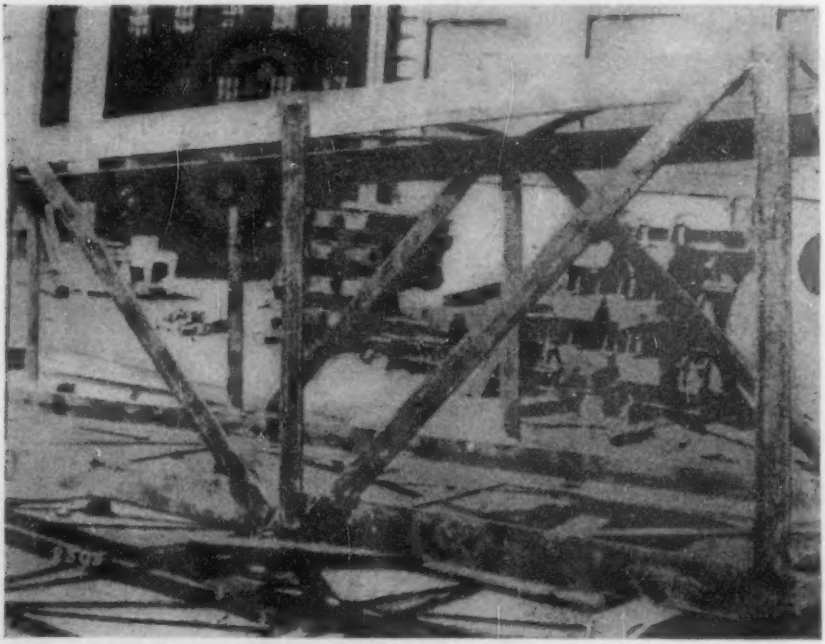


Fig. 17. Arc Welded Steel Derrick Boom.

Muskogee, Oklahoma, an oil storage tank 40 feet in diameter and 20 feet high, all joints being successfully welded by electric arc. Upon completion the tank was successfully tested for 36 hours by

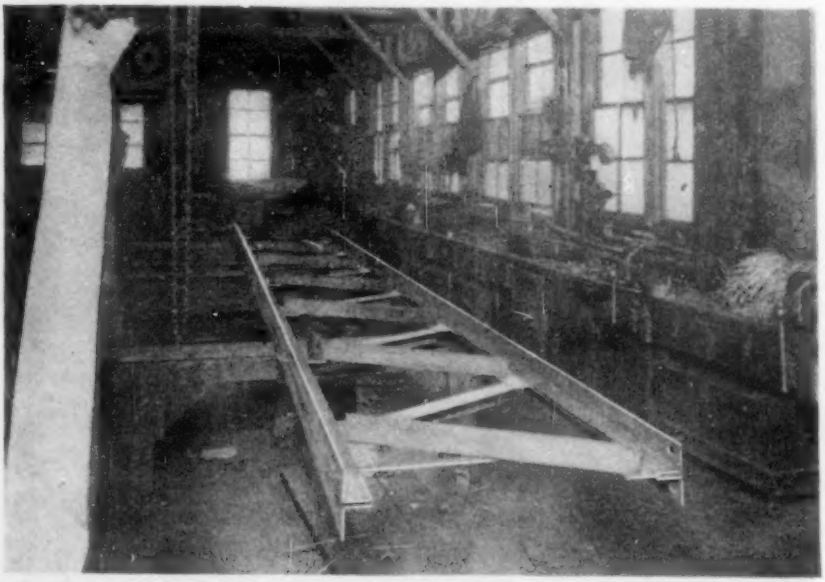


Fig. 18. Method of Electric Welding Structural Parts in the Erection of a Building 40 x 40 x 40, General Electric Plant, Schenectady N. Y.—Illustration shows Top Lattice Girders.

being filled with kerosene. In the same month the Electric Welding Company of America also completed for the Oklahoma Producing & Refining Corporation at Muskogee, Oklahoma, some oil storage tanks 15 feet in diameter by 16 feet high, with all joints electrically arc welded.

At the Schenectady, N. Y. plant of the General Electric Company in 1921 a steel frame 40 feet wide x 40 feet long and 40 feet high was built to serve as a transformer tower, all parts being arc welded. Figs. 18 and 19. The structure contains 34,339 pounds of structural steel and a total of 186 welding hours, including all shop and all field welding, were required to complete the structure.

In 1921 at the Schenectady, N. Y. plant of the General Electric Company a steel bridge connecting two buildings was erected by means of electric welding, only a very few rivets being used at the connection of one of the buildings. Fig. 20. A considerable amount of the welding used in this structure was tack welding instead of continuous fillet welding.

In 1921 at the Schenectady, N. Y. plant of the General Electric Company a large annealing cart was built without the

use of rivets, all joints being arc welded. In this structure tack welding was used, as may be seen in Fig. 21. The cart is used for handling heavy castings in an electric annealing furnace.

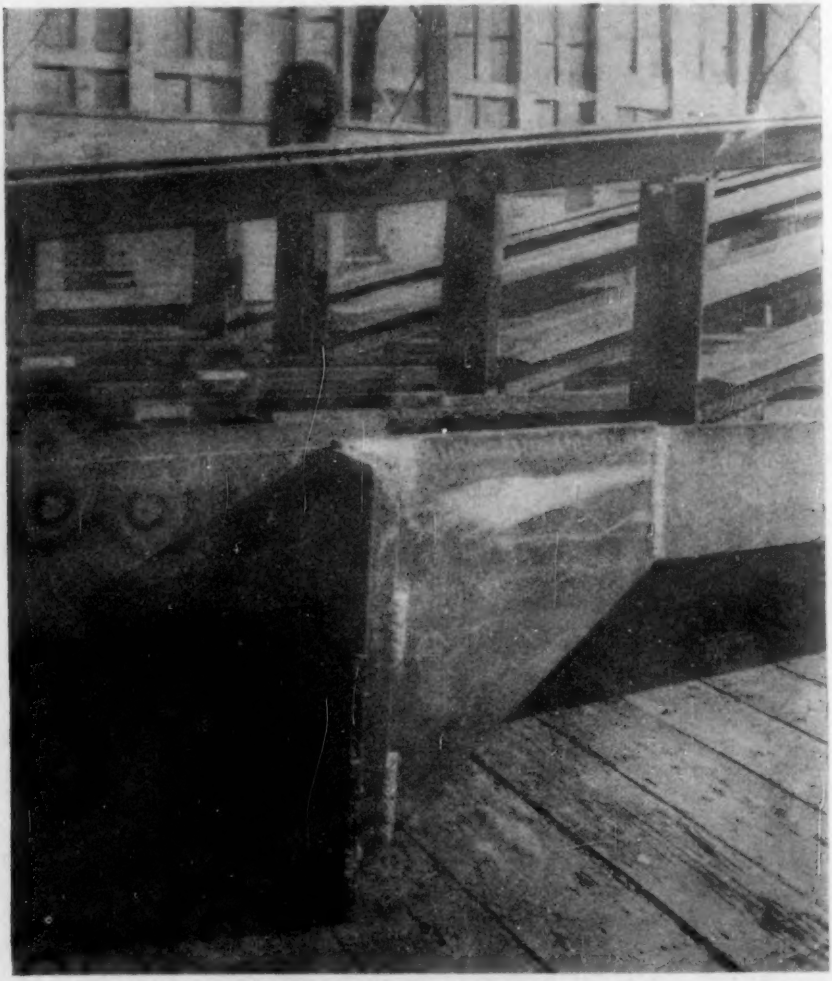


Fig. 19. Method of Joining Crane Runway Bracket to Supporting Column of Transformer Housing.—Building 40 x 40 x 40.

## DESIGN FOR A RIVETED STEEL TRUSS FOR STATIC LOADS

In Figure 22 is shown a preliminary design for an arc welded truss, having a span of 56.4 feet, and carrying a load of 126,000 pounds at the center point C. The following safe unit stresses have been used:

| | |
|---|---|
| Tension | 16,000 lbs per square inch. |
| Compression | $15000 = 50\frac{L}{r}$. |

L = Length of member; r = Radius of gyration of cross-section.

Shearing in beads — 9000 lbs. per square inch.

All welds are of the fillet type, triangular in cross-section and the strength of these fillets are shown in the upper left hand corner of Fig. 22, the 7/16 inch x 7/16 inch fillet having a safe working strength per linear inch of .31 x 9000 = 2790 lbs.; and the ½ inch x ½ inch fillet a working strength of .335 x 9000 = 3195 lbs. To determine the required length of fillet, or bead, to develop in shear a safe strength equal to the stress exerted by the member BC is is merely necessary to divide the srtess, 89200 lbs.

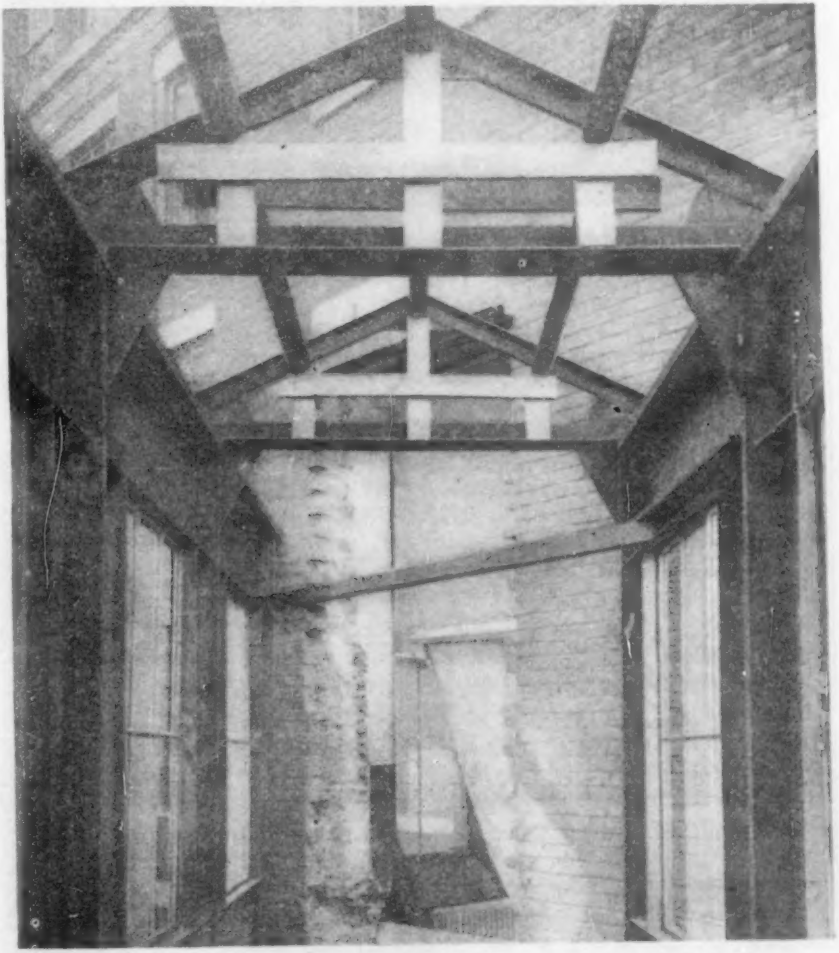


Fig. 20. Interior of Electrically Welded Bridge Showing Roof Trusses and Lateral Posts.

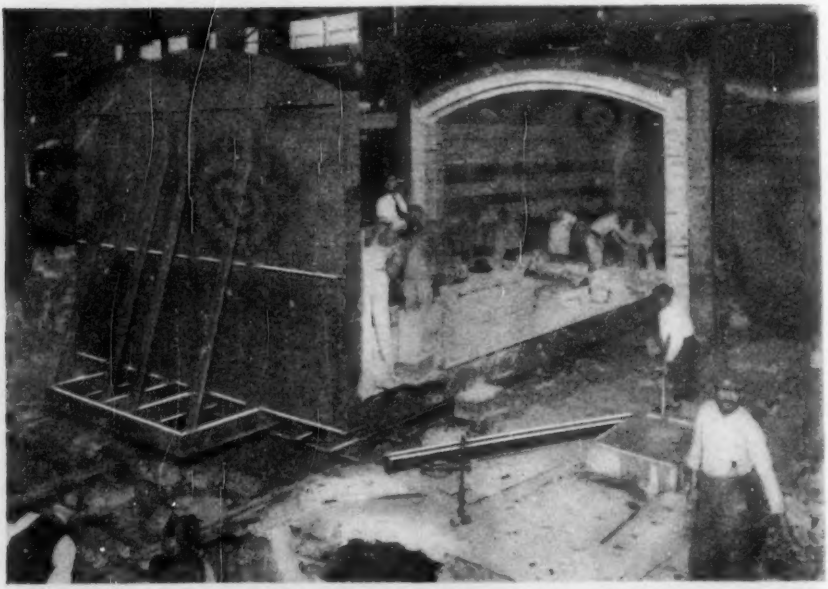


Fig. 21. Large Electrically Welded Annealing Cart for heavy Castings. The White Spots appearing on the Front Door alongside the stiffening beams are Tack Welds. No Rivets were used in building this annealing cart.

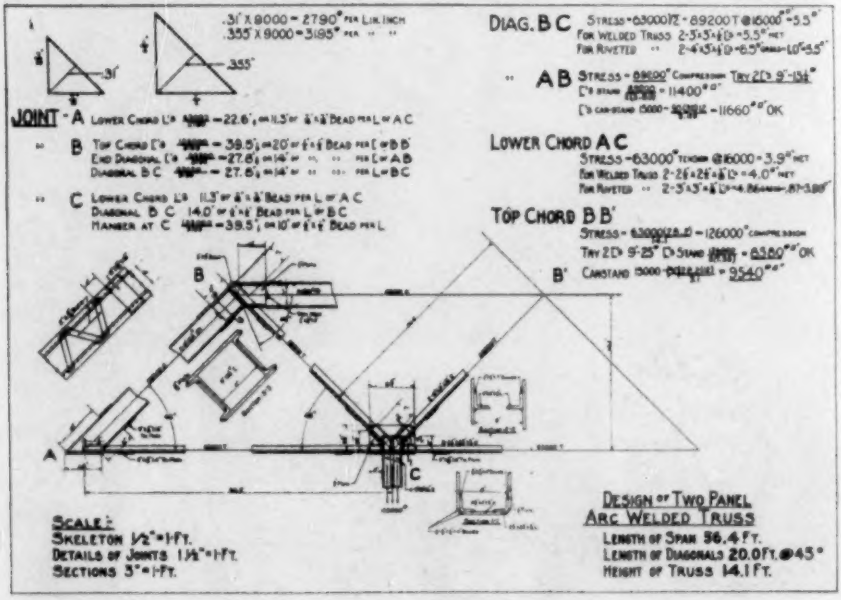

.31" X 9000 = 2790# PER LIN. INCH
.355" X 9000 = 3195# PER " "
.31"
.355"
JOINT "A" LOWER CHORD L^D — 22.6" ON 11.3" OF 5/16" BEAD PER L OF AC
" B TOP CHORD L^D — 39.5" ON 20" OF 5/16" BEAD PER L OF BB'
END DIAGONAL L^D — 27.6" ON 14" OF " " PER L OF AB
DIAGONAL BC — 27.6" ON 14" OF " " PER L OF BC
" C LOWER CHORD L^D 11.3" OF 5/16" BEAD PER L OF AC
DIAGONAL B C 14.0" OF 5/16" BEAD PER L OF BC
MEMBER AT C — 39.5" ON 10" OF 5/16" BEAD PER L
DIAG. BC STRESS = 63000/12 = 89200 T @ 16000# = 5.5"
FOR WELDED TRUSS 2-3"x3"x1/4" D = 5.5" NET
FOR RIVETED " 2-4"x3"x1/4" D = 6.5" GROSS — LOSS = 5.5"
" AB STRESS = 89200# COMPRESSION TRY 2D 9"-13#
D^S STAND — 11400#
D^S CANSTAND 15000 — 11660# OK
LOWER CHORD AC
STRESS = 63000# TENSION @ 16000 = 3.9" NET
FOR WELDED TRUSS 2-2"x2"x1/4" D = 4.0" NET
FOR RIVETED " 2-3"x3"x1/4" D = 4.8" GROSS
TOP CHORD BB'
STRESS = 63000 X 2.0 = 126000# COMPRESSION
TRY 2D 9"-25# D STAND — 8360#
B' CANSTAND 15000 — 9540#
B
A
C
SCALE:
SKELETON 1/2" = 1 FT.
DETAILS OF JOINTS 1 1/2" = 1 FT.
SECTIONS 3" = 1 FT.
DESIGN OF TWO PANEL ARC WELDED TRUSS
LENGTH OF SPAN 56.4 FT.
LENGTH OF DIAGONALS 20.0 FT. @ 45°
HEIGHT OF TRUSS 14.1 FT.

Fig. 22. Design of Two Panel Arc Welded Truss.

by the safe shearing strength of a ½ inch x ½ inch bead per linear inch, i. e., by 3195 lbs., thus giving 27.8 inches, or 14 inches for each of the two angles of member BC. The compactness of the joints in the electrically welded truss is very noticeable and there is a great saving of material in such joints over the ordinary type of riveted joint. Just what the saving in cost may be is at present a matter of conjecture because we have not had sufficient experience to secure accurate cost data on electric welding of such structures.

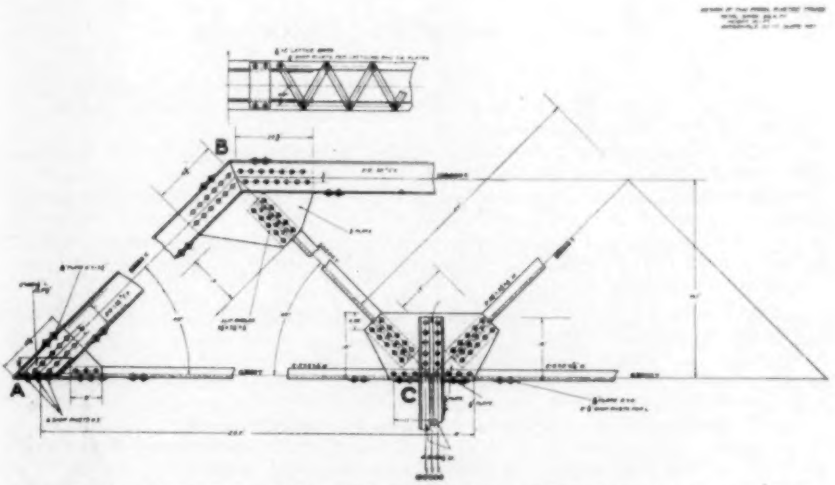



Fig. 23. Design of Two Panel Riveted Truss with Same Loading and Span as for the Welded Truss of Figure 22.

Another very important advantage which the welded truss has over the riveted truss consists in saving material in tension members due to the reduction of cross-section in riveted trusses caused by the rivet holes. For example, in the welded truss shown in Fig 22 the tension member AC is made up of two 2½ inch x 2½ x 7/16 inch angles with a cross-section of 4 sq. inches, and this is also the net section, as there is no reduction of area. In the riveted truss, (Fig. 23) this lower chord member AC is made up of two 3 inch x 3 inch x 7/16 inch angles with a cross area of 4.86 square inches but as the rivet holes take out .87 square inches the net is only 3.99 square inches. The diagonal BC in the riveted truss also suffers loss due to the presence of rivets. The saving of weight in the 4 tension members of the welded truss over the corresponding members of the riveted truss due to reduction of area caused by rivets alone is 304 lbs. The weight of steel in the angles of the 4 tension members of the welded truss is 1520 lbs., and weight in the 4 corresponding members of the riveted truss is 1824 lbs. The saving by the use of the welded truss so far as main tension members are concerned is 16 2/3% of the weight

of metal in the 4 riveted tension members. No rivets have been used in the welded truss shown in Fig. 22, but perhaps a more careful study would show that greater economy could be secured by using rivets in some places and welding in others. For example, it may be desirable to use rivets in the lattice bars of the compression members which in Fig. 22 are shown welded.

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1. Ease of Operation.
2. Steadiness of the arc (it does not sputter or go out).
3. Simplicity of equipment.

—each of which are fully explained in following advertisements.

## Lincoln Electric Company

**General Offices and Factory**

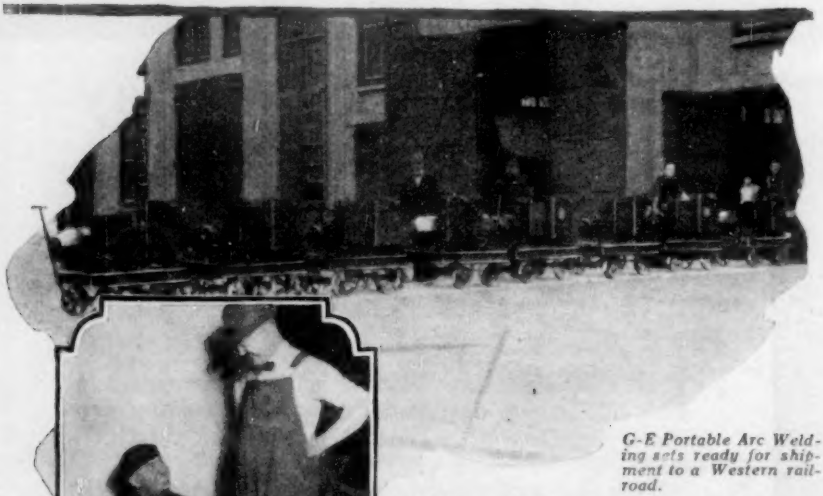
**Cleveland, Ohio**

**The Lincoln Electric Company of Canada, Ltd., Toronto - Montreal**

BRANCH OFFICES:

New York City, Cincinnati, Pittsburgh, Buffalo, Detroit, Chicago, Fort Worth, Texas, Philadelphia, Charlotte, N. C., Minneapolis, London, England, Los Angeles, Boston

***Give a good welder the right arc welding equipment—and just watch the sparks fly!***



*G-E Portable Arc Welding sets ready for shipment to a Western railroad.*

*G-E Arc Welding Sets make the boss and the welder fast friends—because neither can find any reason for kicks.*

## "Good news, Tom! your next outfit's a G-E"

"That's the talk, Mr. Burns! I'll show you some real welding with that set. It's like putting an old pal on the job with me—you know I had one in the other shop, and hung up a record for good strong welds."

"No wonder you wanted a G-E on this job."

"Check me as often as you like on its making good—steady arc easy to hold, good penetration, welds overhead slick as new metal—saves you money all the time."

Dick and Harry use G-E arc welding sets same as Tom—and they're glad to speak right up about them too. Bulletins describing G-E welding equipment and the G-E welding school sent on request. Write our nearest office.

**General Electric Company**

General Office Schenectady, N.Y.

Sales Offices in all large cities

43B-662

# PAGE-ARMCO
## GAS WELDING RODS

PAGE-ARMCO Welding Rods remove all doubt regarding the character of the welding metal.

They are the purest iron made commercially and a recognized standard.

Conform in all respects to A. W. S. specifications, Grade G-No. 1-A.

Yellow tag. Ends of rods colored yellow.

PAGE STEEL and WIRE COMPANY
BRIDGEPORT, CONNECTICUT
Chicago, New York, Pittsburgh, Portland, Ore., San Francisco.

Essentials for Safe and Reliable Electric Arc Welding

**WANAMAKER COATED ELECTRODES and TECOR ACCESSORIES**

*Write for Booklet*

**Transportation Engineering Corporation**

15 PARK ROW
NEW YORK

220 SO. STATE STREET
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*For Sale*

**BOUND VOLUME of the JOURNAL of the AMERICAN WELDING SOCIETY**

Bound volumes of the Journal for Year 1922, may be obtained at $5.00 per copy by placing orders with the Secretary of the Society. All orders must be accompanied by cash.

## *USUALLY* CARBIDE MEANS UNION CARBIDE

*It always does at* 150 *Union Carbide warehouses,* strategically located from Portland, Maine, to San Diego, California, and from Seattle on Puget Sound to Tampa on the Gulf.

Union Carbide is always packed in blue-and-gray drums.

**UNION CARBIDE SALES COMPANY**
**Carbide and Carbon Building—30 East 42nd St.**
**NEW YORK CITY**

*CHICAGO*
*Peoples Gas Bldg.*

*SAN FRANCISCO*
*Balfour Bldg.*

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LINDE is vitally interested in aiding oxygen users. The *will to help* is futile if it is not combined with the *ability to serve.* In a nation-wide business such as the Oxygen Industry, ability to serve depends on physical facilities and organization.

**84**
Linde
Plants
and
Warehouses

Linde Service only *begins* with seeing that your oxygen supply requirements, wherever you may be, are satisfied promptly and fully. It carries on—extends real co-operation and constructive advice as to the efficient and economical use of oxygen. *It belongs to Linde users.*

**THE LINDE AIR PRODUCTS COMPANY**
**Carbide and Carbon Bldg., 30 East 42nd St.**
**New York**
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SINGLE & MULTIPLE ARC MACHINES

**"Color-tipt" Welding Metals For Cast Iron—Bronze—Brass—Malleable Iron—Monelmetal—Steel**

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WELDING MILBURN OXY-ACETYLENE CUTTING

**APPARATUS**

is the result of research and development dating back to the infancy of the industry. The Milburn Line includes all sizes of Welding and Cutting Torches, Regulators and Generators.

**THE ALEXANDER MILBURN COMPANY**

**1416-1428 W. Baltimore Street** **Baltimore, Maryland**

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*Electric Welding*

*For*

*Oxy-Acetylene (Gas) Welding*

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**TRENTON, NEW JERSEY**

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MANY electric railways use RWB Dynamotors because of the advantages which they offer for rail bonding, rail joint welding, track repairs and shop welding. Send for our new catalogue and let us help you with your welding problems.

**RAIL WELDING & BONDING CO.**
**CLEVELAND, OHIO**

## Acetylene in Portable Cylinders for Oxy-Acetylene Welding and Cutting

Supplied in any quantities. Do you understand our free loan plan? If not, we are glad to explain.

Supplied in the following sized cylinders.

**10″ x 30″ size—capacity approx. 125 cu. ft.**
**12″ x 36″ size—capacity approx. 225 cu. ft.**
**12″ x 44″ size—capacity approx. 275 cu. ft.**

Prompt and efficient service through plants and warehouses.

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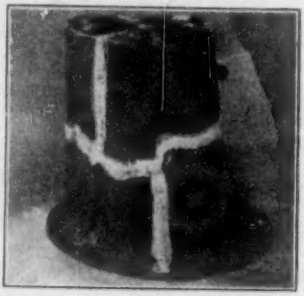

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**Are you welding cracked water jackets, crankcases and frames without dismantling.**

**The ALTERNARC will do it without preheating or warping and at a very low cost.**

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**Telephone Waverly 7802-3**

**Service for New England on Welding Wire Requirements**

**ARMCO WELDING WIRE**

**In Boston Stock**

FOR ELECTRIC WELDING
*Armco Blue Label* in 14 inch lengths.
On reels for G-E Automatic Welding Equipment.

FOR GAS WELDING
*Armco Yellow Label* in 36 inch lengths.
Also Cast Iron, Tobin Bronze, Alum, etc.

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**Permanent Repairs of Heavy Broken**

**Shafts** — **Housings**
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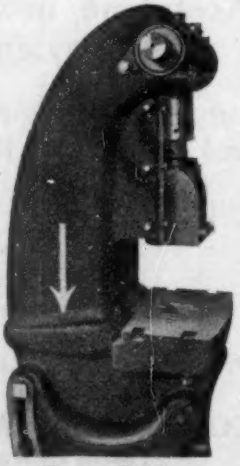

Thermit Weld on Punch Frame

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Properly designed and built to give best service and satisfaction with the least possible attention

Single Operator, Variable-Voltage Type, Portable Unit with Canopy Top

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## For Oxyacetylene Welding and Cutting

SERVICE

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*Air Reduction Sales Company maintains its own Apparatus Repair Shop in each Airco District Office city.*

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*"Airco Oxygen and Acetylene Service is Good Service"*